

The Transformation of Energy Markets: China in a Global Context

**Final Report to Australia China Natural Gas
Technology Partnership Fund (ACNGTPF)**

**Peter Sheehan, Fanghong Sun, Steven Parker, Bruce Mountain and
Enjiang Cheng**

Victoria Institute of Strategic Economic Studies
Victoria University
Melbourne
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Victoria Institute of Strategic Economic Studies
Victoria University
Melbourne, Australia

For further information contact:

Peter Sheehan

T +613 9919 1331

F +613 9919 1350

Peter.sheehan@vu.edu.au

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List of Acronyms

bcm	Billion cubic meters
DRC	Development Research Centre (within China's State Council)
EI	Energy intensity
ERI	Energy Research Institute (within the NDRC)
FYP	Five-Year Plan
IMAR	Inner Mongolia Autonomous Region
IPCC	Intergovernmental Panel on Climate Change
NBS	National Bureau of Statistics of China
NDRC	National Development and Reform Commission, China
SCE	Standard coal equivalent

Overview

For a decade, China has been seeking to restructure its economy and to make its energy sector cleaner and more efficient, both in terms of air pollution and greenhouse gases. These efforts were given new intensity in 2013, in the wake of the ‘air pollution shock’ of that year and continuing concern about climate change. With air pollution still serious in 2017 and the impact of climate change being increasingly felt, these issues remain central objectives of policy. The overall strategy which is now in place has been drawn together in the *Strategic Plan for the Energy Production and Consumption Revolution 2016-30*, released on 25 April 2017 by the National Development and Reform Commission (NDRC) and the National Energy Administration (NEA). This document provides a striking demonstration of the range of measures being implemented and their strategic integration to achieve continuing change in China’s energy sector. This report examines the recent and likely future impact of the many of the measures which are now in place, and explores some of the limitations in policy outcomes to date.

Two major achievements

The past three years have seen two remarkable achievements: the sharp reduction in the rate of growth of total energy use¹ in China and the absolute reduction in coal use. The annual rate of growth of total energy use has fallen by two-thirds between 2008-13 and 2013-16, from 5.4% in the former period to 1.5% in the latter. This has reflected both a slowing in the GDP growth rate within the two periods (from 9.0% to 7.0%) and a somewhat more rapid reduction in energy use per unit of real GDP, from 5.1% per annum over 2008-13 to 5.4% per annum over the last three years. The change in the consumption of coal has been even more dramatic, although there are various numbers provided by the National Bureau of Statistics. According to the energy consumption data, over 2008-13 coal consumption rose by 4.2% per annum, but in the last three years it has fallen at a rate of 1.3% pa, and is nearly 4% lower in 2016 than in 2013. The recently published coal balance sheet data suggest that a much larger fall in coal consumption may have taken place over 2013-16.

A distinctive feature of China’s energy system is the dominant role of six energy intensive industries² in total energy use: in 2007 these six industries accounted for 53.6% of China’s energy use but only 14.1% of GDP. While their share of GDP did not fall significantly over 2013-16, their energy intensity (energy use per unit of value added) continued to fall at about 6% per annum even as overall GDP growth rates slowed. This was an important factor contributing to slower growth in energy use overall – energy use in these industries rose only 0.3% per annum over 2013-16 against 4.6% over 2008-13 – although slower growth was also evident in other sectors of the economy.

For most industries, covering the three large energy intensive industries, light industries and the service sector excluding transport, there have been strong and continuing reductions in energy use

¹ Total energy use or total energy consumption, as used here, refers to the concept used by China’s National Bureau of Statistics (NBS). It is different from final consumption as used in international energy statistics, such as those of the International Energy Agency (IEA, but is close to total primary demand in those data sets. See Panel 1.

² The six industries are petroleum, coking and nuclear fuel; chemical materials and products; ferrous metals; non-ferrous metals; non-metallic minerals; and electricity, water and gas (EGW). Within these six, we give special attention to three – chemical materials and products; ferrous metals and non-metallic minerals – which are referred to as ‘three large energy intensive industries’.

per unit of value added over the past nine years. This has underpinned the continued reduction in overall energy use per unit of GDP of over 5% over this period. Energy intensity fell by 50% in these three industries between 2007 and 2016, even as their share of GDP rose, and over half of the overall energy savings over 2007-16 from lower intensity were in these three industries. But in the three other energy intensive industries, the fall in energy intensity has been much lower, and total energy use has continued to increase at about 5% per annum. A similar situation applies in transport, where there has been little change in energy intensity and energy use has grown by at an even greater rate.

The sharp slowing in energy use since 2007 has reflected slower GDP growth and continued falls in energy intensity, but little has been achieved in terms of changing the structure of the economy. The share of the six energy intensive industries in GDP rose slightly from 14.1% to 14.3% over 2007-16, while the share of the much less intensive light industry and mining fell from 27.1% to 25.7%. This failure to achieve any substantial restructuring in the economy towards less energy intensive industries remains a major issue for policy.

In terms of the shift from growth to decline in overall coal use, our analysis identifies four factors driving this change:

- The six energy intensive industries account for about three quarters of China's final consumption of coal, so that the slowing in their energy use has had a direct impact on the demand for coal.
- In addition to the slowing growth of final energy consumption in industry, there has been a shift to increased direct consumption of electricity in industry, at the expense of coal: over the three years 2011-14 electricity consumption in industry grew by 19.0% while coal consumption rose by only 0.5%.
- In terms of electricity generation, there continues to be a sharp shift from coal to clean fuel sources (hydro, nuclear, wind and solar). Over the past three years, 2013-16, the annual rate of growth of non-fossil power generation has been 10.2% per annum, while electricity from coal has grown at only 1.5%.
- Finally, China has also continued to reduce the coal input required to produce a unit of coal-fired power, to the point at which China has become one of the world leaders in this area. Reflecting pressure to close down small, inefficient power stations and a push for over a decade to large, ultra-supercritical plants, net coal consumption per unit of electricity generated has fallen from 380 g/kwh in 2003 to 315 g/kwh in 2015, a fall of 17%.

The conjunction, as a direct result of policy, of these four factors – slowing growth in energy use overall, reduced direct consumption of coal, a shift in power generation away from coal-fired plant and increased efficiency of the remaining coal-fired plant – has created a powerful engine for reducing the role of coal. These factors have been so powerful that it seems highly likely China's coal consumption has peaked and will fall substantially over the next decade or so.

This is so, even though major challenges remain in the energy area as a result of limitations in policy to date and of broader global trends. We distinguish and discuss four such challenges. Effective action to meet these challenges would greatly enhance the transformation of China's energy system.

Four key challenges related to energy use

Achieving real structural change. A key policy focus has been to achieve structural change in the economy to reduce energy use. Here we measure such structural change primarily in terms of the share of the six energy intensive industries in GDP. While the rate of growth of these industries has been falling, this has been broadly in line with the slowing in the overall economy, so that reducing their share remains an elusive goal of policy: the share of these industries in GDP was a little higher in 2016 than in 2007. Two factors work against achieving a reduced share for these industries. One is the tendency for the Government to support growth, in the face of structural changes elsewhere, through monetary policy and infrastructure investment. These stimulate investment in building, construction and heavy engineering, and hence increase the demand for the output of the six industries. The second is lack of any advanced program to reform and stimulate the service industries. Although there have been various development plans for specific service sectors, including science and technology, health, education, and domestic commerce, the service sector as whole is not sufficiently addressed in total national economic structural change strategy. It is important for structural change to grow the industries which will over time employ the human and capital resources currently used in heavy industry.

Reducing the growth of oil use. While coal use has been falling, China's oil use has continued to rise unabated, growing by 3.8% over 2013-16 (including by over 5% in 2016) after 5.9% over 2008-13. A significant part of China's oil consumption is in industry, but this component has been growing slowly. Rapid growth continues in the bulk of China's oil use which is in final oil consumption outside of industry, especially the transport sector. With the number of motor vehicles in China increasing rapidly and the continued explosion of air travel, the development of railways systems and the shift to public transport modes in major cities have not been sufficient to curb oil use. If China is to reduce the growth of oil use, more extensive programs to increase the fuel efficiency of the existing stock of vehicles may be necessary.

Increasing the role of natural gas. With ample supplies of cheap coal, China's use of natural gas has been, and remains, low relative to advanced countries. This is so even though natural gas consumption has risen by 12.7% per annum over 2007-16. The share of natural gas in final energy consumption in China in 2014 was only about 12% of that in the OECD (4.2% to 35.6%), with the differential being marked in all of the energy intensive industries. Outside industry, the Chinese share of gas in total final consumption is about half of the OECD share. The combination of market forces and policy support for cleaner fuels is likely to drive continued increases in the share of natural gas in China's fuel use, especially in a regime of lower international gas prices and amply gas supplies available to China, both through pipelines and LNG.

Completing the national electricity grid. China faces complex issues creating a modern, market-based electricity grid across the country, moving from a system based on command economy principles and with strong local elements of control. While building such a power grid, it also has to address the new issues, which many countries with well-developed power networks are grappling with, of adjusting power networks to high and rising proportions of intermittent renewable generation. One symptom of this in China is the relatively high level of curtailment of wind and solar energy in China. These issues are reviewed in this report, using a comparison with Australia, and are an ongoing intense policy focus in China. Addressing this challenge is an ongoing process of building

physical and technological infrastructure, market processes and institutions with the appropriate degree of separation to allow markets to operate smoothly.

Projections of energy use and emissions to 2025

We express the themes of this report in a set of projections of China's energy use out to 2025. These projections are not intended as forecasts of energy use – many factors can influence final outcomes over that time frame – but as indicative projections to illustrate the likely role of the key mechanisms identified and of future policy responses. Three main cases are explored, and all assume a common path for aggregate GDP, with GDP growth slowing gradually from 6.7% in 2016 to 5.7% by 2025. The *base case* involves the continuing outcomes of current policy settings as we see them: industry-specific rates of reduction in energy intensity continuing, but at a slower rate than over 2007-16 and no change in the share of the six energy-intensive industries in GDP. *Policy case 1* adds substantial structural change to the base case, with the rates of growth of value added in the six energy intensive industries falling progressively, both relative to their 2013-16 rates and to those of other industries, so that their share of GDP falls from 14.3% in 2016 to 11.4% in 2025. This is a significant change in the structure of the economy over that period. *Policy case 2* adds further reductions in energy intensive, by assuming the further enhancements to policy enable 100% of the annual rates of reduction achieved over 2007-16 (and 2013-16 for transport) to be continued through to 2025.

These projections indicate that China is likely to remain in a period of low energy growth through to 2025, with growth in energy use in the base case being less than 2% per annum over 2016-25. This result assumes the continuation of the strong policy settings that are currently in place. But if, as a result of market forces or further policy impacts, the role of the energy intensive industries is reduced, this will lead to a further slowing of energy, as will maintaining the rates of reduction in emissions intensity evident in recent years. Slow growth in energy use will assist China to address the issues of pollution and environmental damage, especially in the context of a rapid decline in the share of coal. But it is also likely to make the problems of overcapacity in energy production and the costs associated with stranded assets more acute, as well as making the building of more efficient, and market-based institutions more complex.

It is to be noted that energy use in many advanced economies has been falling in recent years, and for the OECD region as a whole, total primary energy consumption was 3% lower in 2015 than in 2005. China remains a developing country with a strong rate of economic growth, and will see continued growth in energy use for the foreseeable future. But as its economy modernizes, adopts more efficient technologies and becomes increasingly service oriented, this growth will moderate further.

This analysis, and hence these projections, uses National Bureau of Statistics of China (NBS) data on energy consumption and our data on real value added by industry, constructed on the basis of NBS data. As a result, these projections do not distinguish types of energy use (whether final consumption or transformation), nor the composition of energy use by fuel. We have built a simple model, based on the IEA data, to take these aggregate projections and break them down by type of energy use and fuel. The results of this work will be reported at a later date.

Conclusion

On 25 April 2017, China's National Development and Reform Commission (NDRC) and the National Energy Administration (NEA) released the *Strategic Plan for the Energy Production and Consumption Revolution 2016-30*, perhaps the first long-term strategic plan for China's energy sector as a whole. This is an impressive document, which lays out in an integrated way the wide range of actions that need to be taken in many different areas to achieve China's goals. The key strategic themes are safety of energy supply of fuel sources, a major emphasis on energy saving to achieve much greater efficiency in energy use, a focus on green and low carbon emission development and a requirement for technological and institutional innovation throughout the energy sector.

The Plan's central quantitative goals are:

- (i) to hold total energy consumption to within 5000 Mt SCE in 2020 and within 6000 Mt SCE in 2030, implying upper level growth rates of 3.5% pa over 2016-20 and over 1.8 % pa 2020-30;
- (ii) to ensure that non-fossil sources account for 15% of energy use by 2020 and 20% by 2030;
- (iii) to achieve a 15% share of total energy consumption for natural gas by 2030; and
- (iv) to reduce carbon emissions per unit of GDP by 18% over 2015-20 and by 65% between 2005 and 2030, and to ensure that these emissions peak around 2030.

In our assessment, these goals are modest and more is likely to be achieved given the recent developments and the strategic plans being put in place. For example, our base case projection of energy use is about 7% below the plan's upper limit in 2020, and also about 7% below an implied upper limit for 2025. In the context of slow growth in energy use with ample supplies of non-fossil energy, the 15%/20% target for the share of non-fossil fuel should be achieved well ahead of time. With continuing serious air and land pollution, massive carbon emissions and heavy social costs from overinvestment in energy and industrial infrastructure, more rapid progress than is encapsulated in these goals needs to be achieved to secure the economic and social welfare of the Chinese people.

1. The Changing Pattern of Energy Use in China

1.1 Background and Data Issues

The overall goal of this project is to provide an improved knowledge base, to the Australia China Natural Gas Technology Partnership Fund (ACNGTFP) and to related parties in China and in Australia, on the key global factors influencing China's structural adjustment process and on the progress being made in China in addressing these challenges. The project was funded with two broad objectives:

- (i) to document and analyse the progressive transformation of China's energy structure, with particular reference to the role of gas and renewables, and in this context,
- (ii) to document and analyse the ongoing dynamics of the global competition between natural gas and renewables as the share of coal and oil declines, and to project potential future outcomes of that competition.

One agreed starting point was that a workshop would be held in Beijing after the completion of the first stage of the project, to obtain the views and guidance of the Chinese participants in ACNGTFP and other leading Chinese experts on the key issues and on research directions. With the strong cooperation of the National Energy Administration (NEA), this workshop was held in the offices of the National Development and Reform Commission in Beijing on 6 April 2016. The meeting was chaired by Mr Liu Deshun of NEA. The Chinese experts who attended, on the invitation of NEA, are listed in Box 1. Dr Cheng and Professor Sheehan of VISES attended and made presentations and extensive discussion ensued, with the conclusions of the meeting summarized by Mr Liu. The meeting was most valuable in defining future directions and we thank Mr Liu and his colleagues for their involvement.

Box 1 List of attendees at ACNGTFP Project Workshop, Beijing, 6 April 2016

Liu Deshun (Chair), Director General, Oil and Natural Gas Department, National Energy Administration
Li Junfeng, Director General, National Climate Change Strategy Research and International Cooperation Centre, NDRC
Wang Zhen, Deputy Director, China Oil Policy Research Centre, Petrol China
Yan Jiantao, Chief Expert of China Policy, Industry and Supervision, BP China
Zheng Xinye, Professor, Deputy Dean, College of Economics, Renmin University, China
Liu Xiaoli, Professor and Deputy Director, Energy Economy and Development Centre, ERI, NDRC
Han Baojun, Division Chief, Oil and natural Gas Department, National Energy Administration
Ma Zheng, Oil and Natural Gas Department, National Energy Administration

While many important points were made, we highlight here six key conclusions:

- (i) China's economic transition, over the longer term, should provide the context for the study, while taking account of continuing global developments and rapid technological change.
- (ii) The emphasis on the six energy intensive industries is good, having regard to problems of overcapacity and of the Government's plans for reshaping these industries.
- (iii) Institutional reform, especially in relation to the national power grid and energy pricing, is critical and should be a focus of the project.
- (iv) It is agreed that, as energy use slows and with fossil fuel prices low, the future competition between different fuels will be critical. The analysis of this issue needs to draw heavily on international experience and recognise fully the importance of institutional change in China.

- (v) It is important to emphasise the role of natural gas in China, for China has a huge potential for increasing gas use.
- (vi) Attention needs to be given to effectively integrating the different components of the analysis, to forming a view independent of government expectations and projections, and to drawing policy recommendations for China.

The second stage of the project has been developed taking these conclusions into account, as far as is possible.

In preparing this final report, considerable attention has been given to the data available on China's energy use, principally from the National Bureau of Statistics of China (NBS), but also from the International Energy Agency (IEA). There are some important differences in the ways in which data are reported in these data sets, which complicate the analysis and are outlined in Panel 1. The main issue is the way of reporting total energy consumption and its breakdown by industry. Following international practice, the IEA data distinguish between final energy consumed within an industry (through either the direct consumption of primary fuels such as coal, oil or gas, or through the consumption of secondary fuels such as electricity and heat) and the transformation of the primary fuels into sources such as electricity and heat. As a result, the key measures are final consumption (FC) and total primary energy supply (TPES) or demand (TPED). While the FC and TPES categories are included in the Chinese data, they are treated in a somewhat different way than in the IEA data. In particular, the primary NBS measure of energy use, both generally and by industry, covers all the consumption of primary fuels in both direct consumption and in transformation, and data on final consumption by industry are not available from NBS. We refer to the NBS aggregate as 'total consumption'.

This key data issue shapes the key elements of the methodology of this report. In this Section 1, we largely use the NBS data on total consumption to study energy use by industry and fuel, but even here (e.g. in sub-section 1.7 on international comparisons) we revert to the IEA data structure. Elsewhere in the report we rely heavily on the IEA data on China. In Section 4, we report some projections of China's energy use to 2025 using two different methods and data sets. First, we use the analysis of the NBS total consumption data in this section to project total energy demand by industry and sector, without any attempt to project fuel use. Secondly, we use a simple model of China's energy use based on the IEA data to project the final consumption and transformation components of China's energy use, and hence to derive indicative projections on several scenarios of fuel use and CO₂ emissions from energy use.

It is also important to note that agencies measure the energy component of renewable energy sources in several different ways (see Panel 1). China's approach is again distinctive, being quite different to IEA, although similar to that of other international agencies. The issue is how to measure the energy used when a non-fossil fuel is used to create electricity. One extreme, adopted by the Intergovernmental Panel on Climate Change (IPCC), includes only the energy embodied in the electricity produced, while the other, adopted by China, calculates the primary energy used in generating electricity from non-fossil fuels using the average heat rate of all coal-fired power plants in the year in question. The IEA uses an intermediate position. The upshot is that the share of non-fossil electricity in total energy consumption in the IEA data is about half that in the NBS data (Panel 1).

Finally, it should be noted that, with China's coal use changing rapidly, there are significant differences between several indicators of China's coal consumption in 2016 provided by NBS.

The overall strategy which is now in place in China has been drawn together in the *Strategic Plan for the Energy Production and Consumption Revolution 2016-30*, released on 25 April 2017 by the National Development and Reform Commission (NDRC) and the National Energy Administration (NEA). This impressive document, perhaps the first long-term strategic plan for China's energy sector as a whole, provides a striking demonstration of the range of measures being implemented and their strategic integration to achieve continuing change in China's energy sector. The key strategic themes are safety of energy supply of fuel sources, a major emphasis on energy saving to achieve much greater efficiency in energy use, a focus on green and low carbon emission development, and a requirement for technological and institutional innovation throughout the energy sector.

The Plan's central quantitative goals are:

- (i) to hold total energy consumption to within 5000 Mt SCE in 2020 and within 6000 Mt SCE in 2030, implying upper level growth rates of 3.5% pa over 2016-20 and over 1.8 % pa 2020-30;
- (ii) to ensure that non-fossil sources account for 15% of energy use by 2020 and 20% by 2030;
- (iii) to achieve a 15% share of total energy consumption for natural gas by 2030; and
- (iv) to reduce carbon emissions per unit of GDP by 18% over 2015-20 and by 65% between 2005 and 2030, and to ensure that these emissions peak around 2030.

This report examines the recent and likely future impact of the many of the measures which are now in place and are summarised in the NDRC/NEA Plan, taking some account of the changing global context. It also explores some of the limitations in policy outcomes to date, and provides preliminary projections of key energy outcomes on the basis of our analysis.

Panel 1 Data Issues

China's rich energy data, primarily published by the National Bureau of Statistics (NBS), reflects the long history and distinctive structure of China's energy system. For a long time, a small number of state-owned enterprises managed this system under strong central control, with energy use dominated by coal. As a result, China's energy statistics maintain some important characteristics which are distinctive to China and at variance with those of standard international practice, as exemplified in the International Energy Agency (IEA) databases. For example, aggregate energy data are provided in a distinctive Chinese unit (tonnes of standard coal equivalent), not used elsewhere; the main published measure for energy use (e.g. by industry) is total consumption rather than final consumption and total primary energy supply, as normally provided in international sources; and the Chinese measurement of renewable energy is again distinctive, although there is no agreed method used in international data sources. For a valuable review of China energy statistics, see Sinton and Fridley (2002).³ This panel outlines how we address some of these data issues in this report, and what they mean for the approach adopted.

Measures of aggregate energy use

International systems of energy statistics are based on the distinction between final energy consumed within an industry (through either the direct consumption of primary fuels such as coal, oil or gas, or through the consumption of secondary fuels such as electricity and heat) and the energy used in the transformation of the primary fuels into sources such as electricity and heat, and into other forms in which the primary fuels may be used. The sum of energy use through final consumption and transformation processes, plus losses and energy industry own use, gives total primary energy supply (TPES). Thus in the IEA data, energy use by industry is final consumption by industry of primary fuels and electricity, not including transformation processes or energy industry own-use.

By contrast, the central concept in the Chinese data is total consumption, which includes inputs to power and heat generation which are 'distributed to end-use sectors by using the gross heat rate of power generation to convert electricity to standard coal' (Sinton and Fridley 2002, p. 6). Energy industry own-use is also included in total consumption. Final consumption data in the IEA sense do not appear to be available from NBS, but aggregate data on total consumption of energy (including some information on primary fuel type) have been published for 2016. Data on total consumption by industry are available up to 2015, and electricity consumption by industry is available through to 2016.

This difference in the structure of the data available from NBS and IEA leads us to adopt a two-stage approach here. For analysis of energy use (total consumption) and value added by industry, we use the Chinese data to construct energy use per unit of value added, by industry. This enables us to study changes in the structure of Chinese value added and energy intensity by industry, and to undertake some simple projections. But to understand more fully the nature of the changes taking place in the Chinese energy system, it is necessary to separate final consumption from transformation, and to model in more detail the process of transforming primary fuels into electricity and heat. To do so we draw on the IEA database for China and develop a model (outlined in Appendix 1) to analyse and project both elements of China's energy use. This second stage approach also has the advantage of allowing comparisons to be made between China and other countries more readily. The results of this work are not provided here, but will be reported at a later date.

Constructing industry data for value added and total energy consumption for 2015 and 2016

With change occurring so rapidly in China's energy system, it is important to make use of the most recent data for analysis. While aggregate data for both real value added and total energy consumption have been published by NBS, the data by detailed industry are only available up to 2007 for value added and to 2015 for energy use. But data on the annual rate of change in real value added by industry are available from 2007 to 2016; we use these data together with value added in current prices in 2007 to create a series of real value added by industry to 2016, on a 2007 base. In the energy area, electricity consumption by industry is available through to 2016. We analysed the historic relationship for each industry, between consumption of energy and of electricity (including the underlying trend for electricity to provide a growing share of consumption), and used this relationship to estimate energy consumption by industry for 2016, consistent as far as possible with the published aggregate data.

³ Sinton, J.E. and Fridley, D.G. 2002, 'A guide to China's energy statistics', *The Journal of Energy Literature*, June.

The measurement of renewable energy

There are important differences across international agencies in methods for estimating the primary energy content of electricity derived from non-fossil fuels (nuclear, hydro, wind, solar and other renewables), and again China occupies a distinctive position. When coal is used in a power station to generate electricity, the primary energy input in terms of coal is substantially greater than the energy contained in the resulting electricity. But when stored water is used to drive generators to produce electricity, it is less clear what the relationship is between the total energy used and the energy contained in the resulting electricity. More generally, what is the primary energy equivalent of electricity generated by non-fossil fuels?

A range of positions are adopted on this issue by various international agencies and by China (Lewis et al. 2015⁴). At one extreme, the IPCC uses a direct equivalent method, and takes account only of the energy embodied in the electricity. At the other extreme, China calculates the primary energy for all non-fossil sources using the average heat rate of all coal-fired plants in China in the year in question. Other agencies (such as the US Energy Information Administration, BP and the World Energy Council) use a substitution method which gives a result close to that of China. The OECD, IEA and Eurostat use a physical content method, which gives a result close to China's method for nuclear power, but the same as the IPCC method for all other non-fossil sources. Lewis et al. calculate that the upshot of this is that, for 2010, the share of non-fossil primary electricity in total energy in the IEA method (4.2%) is half what it is using the Chinese method (8.4%).

These differences of approach raise no fundamental problems, but can cause confusion in interpreting various targets, especially if both Chinese and IEA data are used. While our modelling of China's electricity production and use is largely based on IEA, we can convert the primary energy content of electricity into the Chinese method as necessary.

Recent data on the consumption of coal

There are several ways of deriving an estimate of coal consumption to 2016 from the NBS data published as at 24 April 2017. The first is the data on aggregate energy consumption by fuel source, but for 2016 only data on total energy consumption and the share of that consumption met by coal (62.0%) are available. This series gives the results provided in the text, that coal consumption in 2016 was 3.8% lower than in 2015 than in 2013. Some coal balance sheet data for 2016 were released on 19 April 2017, and these suggest a more rapid fall in coal consumption. These data show a 14.2% decline over 2013-16 in Chinese domestic coal production and a 14.7% decline in the sum of production and exports. While data on inventory changes and exports are not available for 2016, these figures imply a reduction in coal consumption in China over 2013-16 of at least 10%. In this report we use the former data, the energy consumption by fuel series. But dramatic changes are taking place in China's coal production and use, and these data may understate the decline in China's coal use.

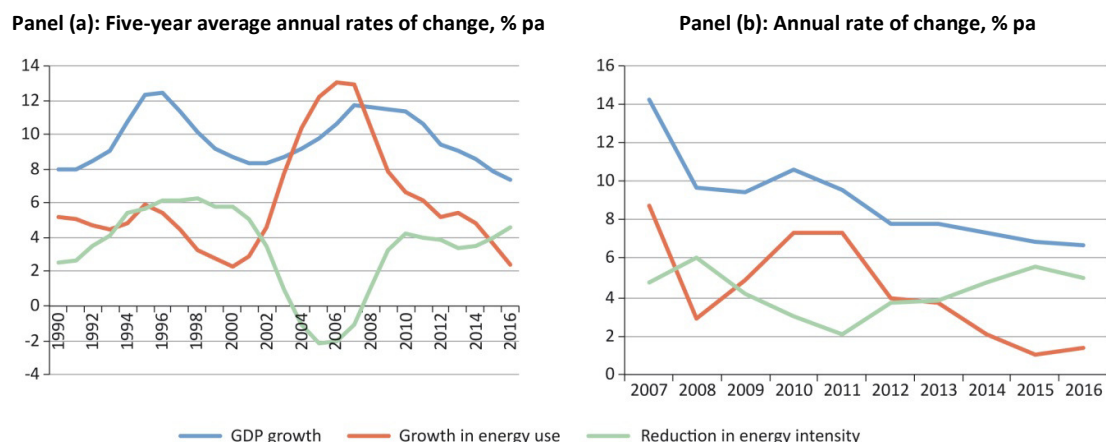
1.2 Energy Use and Energy Intensity

Over the past three decades, the growth in China's energy use has fluctuated considerably, under the influence of powerful national and international forces. This is brought out in panel (a) of Figure 1, which shows the average annual rate of change of real GDP, total energy use and energy intensity (reduction positive) on a five-year moving average basis starting from 1985-90. In the second half of the 1990s, for example, the growth in energy use fell to only 2.3% per annum, even though GDP growth over 1995-2000 averaged 8.6% per annum. This meant that energy intensity – energy use per unit of real value added – fell by about 6% over this period. But China's entry to the WTO in 2001 led to rapid development driven primarily by investment in fixed assets and by exports of manufactured goods. The very high level of investment in turn came mainly from manufacturing, property and infrastructure investment, with some increase in service sector investment. While generating rapid growth, this pattern of development has generated many problems in terms of

⁴ Lewis, J.I., Fridley, D., Price, L.K., Hongyou Lu, and Romankiewicz, J.P. 2015, 'Understanding China's non-fossil energy targets', *Science*, vol. 350, no. 6264, pp. 1034-1036.

unbalanced development, pollution and over-capacity in many areas, as well as in the management of the state-owned enterprises and the indebtedness of the banks. In particular, energy use accelerated rapidly, rising by 12.3% per annum over 2001-06 on average GDP growth of 10.7%, implying an increase in energy intensity of about 1.5% per annum over this period.

Figure 1 GDP growth, energy use and change in energy intensity, China, 1990-2016



Source: NBS and estimates of the authors.

The decade since 2007 has been one of slowing growth in GDP and energy use, with substantial reductions in energy intensity, as policy increasing focuses on energy and environmental issues. This is brought out in the five-year average data in panel (a) of Figure 1, and also in the one year data for 2007-16 in panel (b). Both the five-year average data and the one year data show continuing slowing in the growth of energy use and GDP after 2007, with the pace of the reduction in energy intensity increasing in recent years. As a result of these changes, energy use rose by only 1.5% per annum over the three years 2013-16, in spite of GDP growth of 7.0% per annum, with aggregate energy intensive falling by 5.4% per annum. An important objective of this report is to understand the factors behind these sharp changes and to explore what these factors mean for future trends. While the recent experience has some superficial parallels to that of the period 1995-2000, in fact it represents a very different stage of China's development.

1.3 Energy Use by Industry: Overview

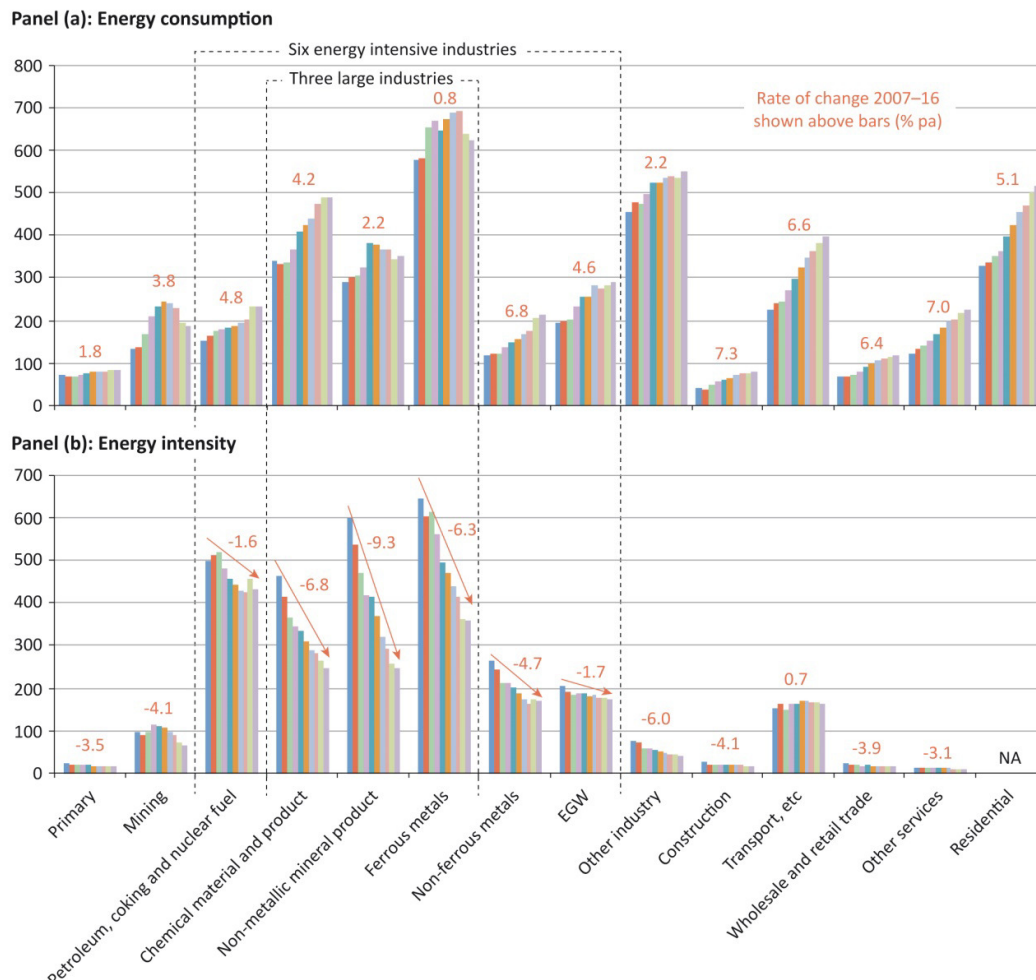
In an international context, China's energy use is distinctive both in terms of industrial structure and fuel type. Here we focus on energy use by industry, using the NBS data on total consumption, and consider fuel type in Section 1.6. In 2007, secondary industry, defined to include mining but exclude construction, accounted for 72.5% of total Chinese energy consumption, while six component secondary industries (discussed below as the 'energy intensive industries') accounted for 53.6% of total energy use. This dominance of industry in overall energy use reflects various aspects of China's historical experience: the strong focus on industry since the founding of the People's Republic in 1949 and especially since the 'opening up' reforms of 1979; the high level of energy use in industry inherited from the command economy period, and the rapid growth of energy use in secondary industry as a whole, and in several industries in particular, after the entry to the WTO in 2001.

Figure 2 and Table 1 provide data on energy use (total consumption) by 14 industries across the whole economy, on which data are available from NBS. Energy use is expressed in million tons

standard coal equivalent. As described in Panel 1 earlier, the value added data are constructed by applying the annual growth rate of industry value added published by NBS to the nominal value added in 2007, hence creating a series for real value added expressed in 2007 prices. Energy intensity is the ratio of energy use per unit of value added.

As mentioned earlier, the annual rate of growth in total energy use in China fell from 12.3% over 2001-07 to 5.0% over 2007-13 and to 1.5% over 2013-16. The rate of growth between the first two periods fell over all industries, with only one exception, mining, where energy use grew by 10.3% per annum over 2007-13. Energy growth rates again fell across all industries between the second pair of periods, this time with two exceptions: petroleum, coking and nuclear fuel and non-ferrous metals. In terms of value added (see Table 1), between 2007-13 and 2013-16 the rates of growth of value added fell across most industries, in many cases substantially, although remaining virtually unchanged for petroleum, coking and nuclear fuel and for transport.

Figure 2 Energy consumption and energy intensity, by industry, China, 2007-16, Mt SCE and %



Source: NBS and estimates of the authors.

Perhaps the most striking feature of these data is the persistent decline in energy intensity over both periods, as the growth in energy use has slowed more rapidly than that of value added. For the whole economy, there were reductions in energy intensity of 5.1% per annum over 2007-13 and of

5.4% over 2013-16, with the reduction over 2013-16 being achieved in spite of slower GDP growth, implying a low rate of growth (1.5% per annum) in overall energy use. This reduction in energy intensity is evident for all 14 industries other than transport over 2007-16 (Figure 2 panel (b)), although rates of change vary sharply across industries and between sub-periods (Table 1 and Figure 2 panel (b)). Energy intensity in the composite transport industry rose by 0.7% per annum over 2007-16, but fell by 1.3% per annum over 2013-16, and remained higher in 2016 than in 2007. This persistent and rapid fall in energy intensity, except for transport, is a remarkable vindication of a consistent application of policy, supported by other factors.

Table 1 Energy consumption levels and changes in energy consumption, value added and energy intensity, by industry, China, 2007-16

	Energy consumption					Value added		Energy intensity	
	2007	2013	2016	2007-13	2013-16	2007-13	2013-16	2007-13	2013-16
	Per cent per annum								
1.Primary	70.7	80.5	83.1	2.2	1.1	6.4	3.8	-3.9	-2.6
2. Mining	132.6	239.2	184.9	10.3	-8.2	10.0	4.6	0.3	-12.3
3. Petroleum, Coking and Nuclear Fuel	153.2	192.6	234.1	3.9	6.7	6.5	6.5	-2.5	0.2
4. Chemical Material and Product	338.5	440.8	490.1	4.5	3.6	13.1	9.2	-7.6	-5.1
5. Non Metallic Mineral Product	289.9	365.6	351.9	3.9	-1.3	15.5	7.4	-10.0	-8.1
6. Ferrous Metals	578.4	688.4	623.5	2.9	-3.2	9.8	3.2	-6.2	-6.3
7. Non Ferrous Metals	117.6	166.2	213.3	5.9	8.7	13.3	9.9	-6.5	-1.1
8. EGW	194.4	281.5	290.8	6.4	1.1	8.1	3.1	-1.6	-1.9
9. Other Industry	453.7	537.0	551.8	2.8	0.9	9.8	6.6	-6.4	-5.4
10. Construction	42.0	70.2	79.3	8.9	4.2	14.2	7.5	-4.7	-3.1
11. Transport, etc.	224.2	348.2	397.0	7.6	4.5	5.8	5.9	1.7	-1.3
12. Wholesale and Retail Trade	67.3	106.0	118.0	7.9	3.7	12.7	7.1	-4.3	-3.2
13. Other Services	122.9	197.6	226.5	8.2	4.6	11.4	8.7	-2.8	-3.7
14. Residential	328.9	455.3	516.0	5.6	4.3	na	na	na	na
Total Energy Consumption	3114.4	4169.1	4360	5.0	1.5	10.5	7.0	-5.1	-5.4
Of which:									
Three industries (4-6)	1206.8	1494.8	1465.5	3.6	-0.7	12.3	6.6	-7.8	-6.8
Other three EI industries (3, 7, 8)	465.2	640.3	738.2	5.5	4.9	9.3	5.9	-3.5	-1.0
Secondary industry (2-9)	586.3	776.2	736.7	4.8	-1.7	9.9	6.3	-4.6	-7.5
All other (1 and 10-14)	856.1	1257.8	1419.9	6.6	4.1	10.6	7.4	-3.6	-3.1

Source: NBS and estimates of the authors.

Given the concentration of Chinese energy use in industry, trends within the industrial sector are especially important. Here we give special attention to six industries often referred to as the ‘energy intensive industries’:

- Petroleum, coking and nuclear fuel;
- Chemical materials and products;
- Non-metallic mineral products;
- Ferrous metal smelting and pressing;
- Non-ferrous metal smelting and pressing; and
- Electricity, gas and water (EGW – own use).

Panel (b) of Figure 2 identifies these six industries as those with the highest energy intensity, especially at the beginning of the period, 2007. As already noted, secondary industry accounted for 72.5% of energy use in 2007 while providing 41.3% of GDP. But this energy use was heavily concentrated on particular sectors. The six energy intensive industries accounted for 53.7% of energy use in 2007 but only 14.1% of GDP, while three of these industries were both large and highly

energy intensive. Thus trends in both energy intensity and value added in these specific industries are of enormous importance.

Within this group we focus on these three large industries – chemical materials and products, non-metallic mineral products and ferrous metals – which have been of particular interest over recent years. These industries accounted for 38.7% of energy use but only 7.8% of GDP in 2007. Indeed it is evident from the data provided in Tables 1 and 2, that trends in these three large industries are quite different from those in the other three energy intensive industries, so these three groups are discussed separately. Two other industry groupings – secondary industry excluding the six industries, and all other industries, namely agriculture and the service sectors – also show distinctive patterns. Thus we discuss trends in energy use and value added below in terms of these four industry groupings.

1.4 Energy Use by Industry: Four Industry Aggregates

The three large energy intensive industries dominate both the level and the change in China's overall energy use, accounting in 2007 for 38.7% of overall energy use but only 7.8% of GDP. This implies a level of energy intensity in 2007 more than seven times that of all other industries in China. Since 2007, energy use by these industries has initially slowed sharply, to 3.6% per annum over 2007-13 (from a rate of 15.9% per annum over 2001-07), and then fallen by 0.7% per annum over 2013-16, even though value added has continued to grow strongly. This means that the reduction in energy intensity since 2007 has been dramatic, with falls of 7.8% and 6.8% per annum over 2007-13 and 2013-16 respectively. The effect of this reduction in energy intensity has been to cut 2016 energy use in these three industries in half – if the 2007 intensities had continued to apply for these industries energy use would have been double what it actually was in 2016 (see Table 3). This is a remarkable change.

Table 2 Energy use, value added and energy intensity, four main industry aggregates, China, 2007-16

	Energy consumption			Value added			Energy intensity		
	Energy use share (%)			Value added share (%)			Energy intensity (level)		
	2007	2013	2016	2007	2013	2016	2007	2013	2016
Three large industries (4-6)	38.7	35.9	33.6	7.8	8.7	8.6	56.9	35.1	28.4
Other three EIs (3, 7, 8)	14.9	15.4	16.9	6.3	5.9	5.7	27.2	22.0	21.3
Other secondary industries (2-9)	18.8	18.6	16.9	27.1	26.2	25.7	8.0	6.0	4.8
All other industries (1 and 10-14)	27.5	30.2	32.6	58.7	59.2	60.0	5.4	4.3	3.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	11.5	8.5	7.2

Source: NBS and estimates of the authors.

The situation with the three other energy intensive industries (numbers 3, 7 and 8 in Table 1) is quite different. Taken as a whole, their energy intensity fell much more slowly than in the three large industries (by 22% rather than 50% over 2007-16), while their share of national value added declined significantly from 6.3% in 2007 to 5.7% in 2016. But even so, with the decline in energy intensity well below the national average the growth in energy use (at over 5%) was above national figure. As a result, their share of energy use rose sharply (from 14.9% to 16.9% over 2007-16).

The other two groups of industries for which data are provided in Tables 1-3 are also interesting. The 'other secondary industries' group consists of mining and light industry generally. This is a large segment of the Chinese economy, including many light export industries, such as textile and clothing,

motor vehicles and information and telecommunications equipment. It accounted for 27.1% of China's GDP in 2007 but, with energy intensity below the national average, for only 18.8% of energy use in 2007. It is striking that over 2007-16 energy intensity in this group of industries continued to fall rapidly, by 5.4% per annum over the period as a whole and more rapidly over 2013-16. The energy intensity of mining was effectively unchanged over 2007-16, when activity was rising rapidly, but has fallen sharply since 2013 as activity has slowed and rationalization has become a reality.

The final group of industries is agriculture and the service industries, including construction, transport, wholesale and retail trade and all other services, and residential energy use. With the exception of transport, most of these industries have low energy intensity and strong reductions in this intensity over 2007-16. For the service industries excluding transport, energy intensity has fallen by over 4% per annum over 2007-13 and by about 3.5% over 2013-16. This is also a remarkable achievement. But, as illustrated in panel (b) of Figure 2, the only one of the 14 industries shown in which energy intensity has risen over 2007-16 is transport.

There are thus several conflicting messages from the industry analysis of energy use. For most industries, covering the three large energy intensive industries, light industries and the service sector excluding transport, there have been strong and continuing reductions in energy use per unit of value added over the past nine years. This has underpinned the continued reduction in overall energy use per unit of GDP of over 5% over this period. But in the three other energy intensive industries, the fall in energy intensity has been much lower, and total energy use has continued to increase at about 5% per annum. A similar situation applies in transport, where there has been little change in energy intensity and energy use has grown by at an even greater rate.

1.5 Understanding the Change in Energy Intensity

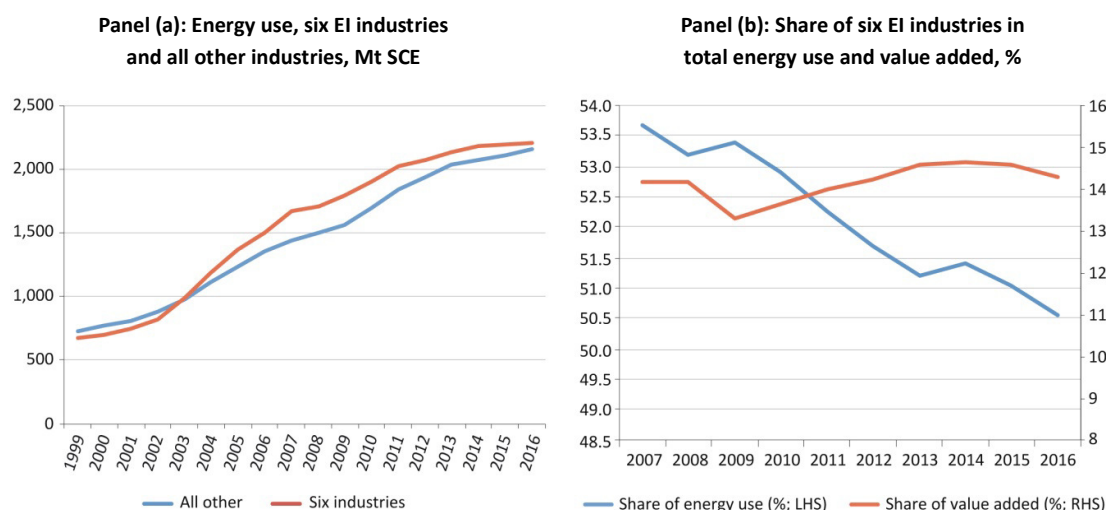
Aggregate intensity can change either because of changes in the intensities of the individual industries that make up the total, or because of changes in the structure of value added across industries with different intensities. In particular the observed major reduction over 2007-16 in China's overall energy intensity could reflect specific reductions in energy intensity (EI) in industries or a reduction the share of value added being generated in energy intensive industries. The Government's policy has been to achieve both reductions in EI within industries, but also structural change to less energy intensive industries.

Here we measure structural change in terms of value added at constant rather than current prices, to avoid misleading conclusions arising from differential rates of growth of prices across industries. What is clear is that, over the period 2007-16 as a whole, there has been no progress towards a less energy intensive economic structure, although some modest progress was made over 2013-16. The share of total value added in the three most energy intensive industries rose from 7.8% in 2007 to 8.7%, on rapid growth of 12.3% per annum. This growth slowed to 6.6% over 2013-16, a little below that of real GDP as a whole (7.0%), but the three industry share remained at 8.6% in 2016.

The story is a little different with the three other energy intensive industries, whose share of value added declined steadily over the two periods, from 6.3% in 2007 to 5.7% in 2016, even as the decline in their energy intensity slowed and their share of energy use rose sharply (from 14.9% to 16.9% over 2007-16). Panel (b) of Figure 3 shows that, while the average energy intensity for six industries as a whole has fallen strongly over 2007-13, their share of GDP has risen marginally over that time.

Trends in the final group of industries – light industries and mining – are also relevant to the structural change issue, as their energy intensity is less than one quarter of that of the six EI industries. One objective of policy has been to shift activity within secondary industry from more energy intensive to less energy intensive industries. But over 2007-16, the share of real value added has fallen steadily, from 27.1% in 2007 to 25.7% in 2016, and has fallen in both sub-periods. This failure to achieve any substantial restructuring in the economy towards less energy intensive industries remains a major issue for policy.

Figure 3 Energy use and value added in selected industries



Source: NBS and estimates of the authors.

Thus the reasons for the rapid fall in national energy intensity over 2007-13, at over 5% per annum, lie entirely with falling intensity at the individual industry level. One way of quantifying the contribution of the falling intensity by industry is to project what the level of energy use would have been in 2016, given the actual path of value added, if the 2007 intensity levels had continued to prevail in 2016. The results of such an exercise are provided in Table 3.

Table 3 Savings in energy use in 2016, due to declines in energy intensity 2007, Mt SCE and per cent

Energy use (Mt SCE)					Reductions in energy use by 2016	Savings in 2016 as a share of:	
	Actual energy use (Mt SCE)		Projected energy use at 2007 EI levels (Mt SCE)		(Mt SCE)	Actual 2006 energy use	Total savings
	2013	2016	2013	2016		(%)	(%)
Three large industries (4-6)	1495	1465	2426	2936	1470.3	100.3	54.4
Other three EIs (3, 7, 8)	640	738	793	943	204.5	27.7	7.6
Other secondary industries (2-9)	776	737	1032	1238	501.5	68.1	18.6
All other industries (1 and 10-14)	1258	1420	1571	1947	526.8	37.1	19.5
Total	4169	4360	5822	7063	2703.1	62.0	100.0

Source: NBS and estimates of the authors.

Actual energy use in 2016 was 4360 Mt SCE, but if 2007 EIs had continued to apply at the individual level that energy use would have been 7063 Mt, or 62% higher than what was actually the case. Of these savings of 2703 Mt, 54.4% came from the three large EI industries even though they amount

to only about 8.5% of GDP. The contribution of the other three EI industries was small (7.6%), while significant contributions came from both other secondary industries (18.6%) and the service industries (19.5%).

A full analysis of the reasons for increased energy efficiency in each industry is a major task, and beyond the scope of this report. Here we note some of the main factors applying across the board, with some more specific comments on the three large EI industries. There are five general reasons that can be cited as lying behind the rise in within-industry energy efficiency in China over 2007-16:

- *Global processes of technological change and efficiency.* China's economy is now closely integrated into the world economy, and rapid development of more energy efficient technologies and processes is taking place both in China and internationally. In the OECD, for example, total final energy consumption per unit of GDP has fallen by 1.5% per annum since 2000. These ongoing processes should continue to contribute to rising efficiency of energy use in China.
- *Strong policy focus within China.* Over this period there has been a strong policy focus on increased energy efficiency, reflected for example in recent national Five-Year Plans and in their counterparts by industry and region. This policy emphasis has intensified since 2013, and is likely to continue for some time, as indicated in the NDRC/NEA strategic plan cited earlier.
- *Inherited inefficiencies, reflecting China's development path.* In terms of energy use, the command economy period in China, in which energy use was determined by planning allocations rather than by demand or commercial considerations, lasted until the second half of the 1990s. When the controls began to be released at the time of China's entry into the WTO, energy demand exploded and total energy use doubled between 2001 and 2007. This path undoubtedly left significant inefficiencies in energy use to be addressed.
- *Overcapacity and rationalisation processes.* Many Chinese industries face, and have faced for some time, serious issues arising from capacity running well ahead of demand and production. With demand growing only modestly and exports markets becoming more difficult, rationalisation processes driven by both government policy and commercial realities are continuing. In such processes, the least efficient firms and units are likely to close, increasing the overall efficiency (including the energy efficiency) of the industries.
- *Possible structural shifts within industries.* The analysis conducted here uses 14 industries, but each of these industries is complex aggregates, with many component sub-industries. It is therefore likely that compositional change within these industries influences overall energy intensity, as production capacity shifts from less to more efficient industries.

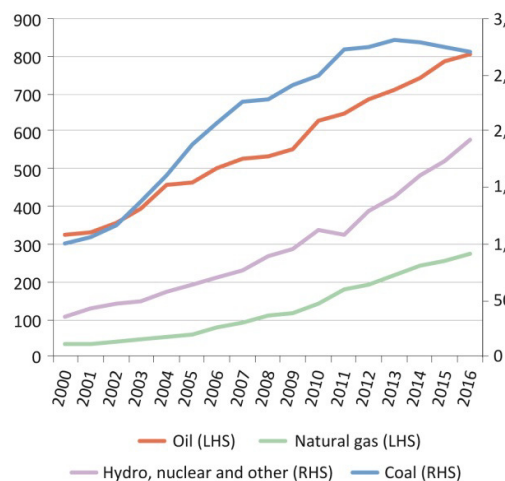
1.6 Energy Use by Fuel and Industry

As shown in Figure 4 and Table 4, the dominant change in fuel use in China since 2007 has been the sharp decline in the share of coal consumption, from 72.5% of total energy use in 2007 to 62.0% in 2016, and the absolute decline in coal use of about 4% (and perhaps more) since 2013. Since 2007, and more especially since 2013, the share of all other fuel types has risen to fill the gap left by coal. The natural gas share, while still low, more than doubled between 2007 and 2016, with gas consumption rising at 12.7% over 2007-16. Consumption of non-fossil fuels in total has continued to

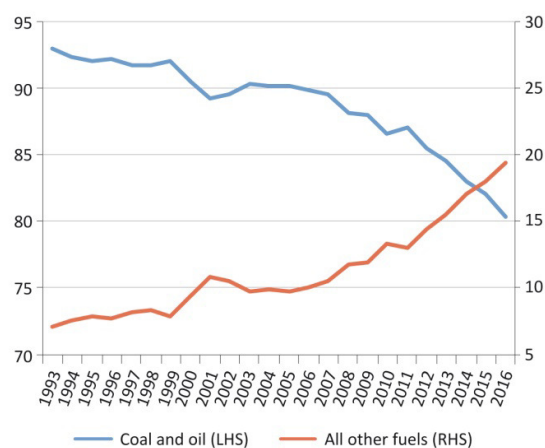
rise by over 10% per annum over the past decade,⁵ but the impact of this rapid growth on the composition of energy use has become more pronounced as total energy use has slowed. Over the past three years, consumption of nuclear fuels and of wind, solar and other renewables has risen by over 20% per annum, in spite of considerable curtailment of renewable electricity production (see Section 2).

Figure 4 Total energy consumption, China, 2000-16, by primary fuel

Panel (a): Mt SCE and shares of total energy consumption



Panel (b): %



Source: NBS and estimates of the authors.

The other main feature of China's recent energy use is the continued rapid rise in oil use, evident in both panel (a) of Figure 4 and in Table 4. Between 2013 and 2016, for example, oil use rose by 4.2% per annum, nearly three times the rate of growth in overall energy use. China's oil use is almost all in the transport sector, so the high rate of growth of oil use reflects the phenomena of a rapid rise in energy use, with little reduction in energy intensity, in transport. This issue is discussed further below.

⁵ It should be noted that these figures use the Chinese estimates of the energy used in renewable electricity generation, and the share of most non-fossil sources is lower in the IEA data. See Panel 1 above. The measurement difference mainly affect the level of energy use from renewable source, and hence the share in total energy use, but should not affect the rate of growth of renewable energy.

Table 4 Energy consumption by fuel source, % of total

	Share to total energy use (%)				Rate of change in energy use (% pa)		
	2001	2007	2013	2016	2001-07	2007-13	2013-16
Coal	68.0	72.5	67.4	62.0	13.5	3.7	-1.3
Oil	21.2	17.0	17.1	18.5	8.2	5.1	4.2
Natural gas	2.4	3.0	5.3	6.3	16.5	15.4	7.5
All other	8.4	7.5	9.4	13.2	10.2	10.5	10.6
Of which:							
Hydro	6.6	5.3	6.9	7.3 ¹	8.2	9.6	3.7 ¹
Nuclear	0.4	0.6	0.8	1.5 ¹	20.1	10.9	22.9 ¹
Wind, solar and all other	1.4	1.6	2.5	4.4 ¹	14.8	13.0	22.5 ¹
Total	100.0	100.0	100.0	100.0	12.3	5.0	1.5

Note: ¹Disaggregated data for 2016 on energy use by these fuel types is not published. Figures shown are estimated by the authors on the basis of the 'all other' figure for 2016 and disaggregated data on electricity production.

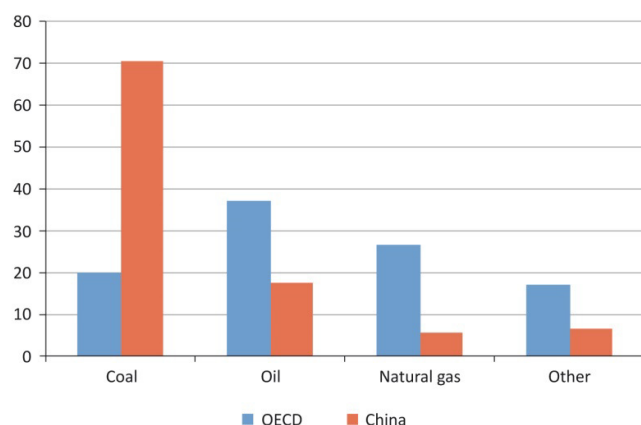
Source: NBS and estimates of the authors.

In spite of the quite different trends in coal use and oil use, the total use of these two fuels has continued to fall sharply as a share of total energy use (see Figure 4, panel (b)). This reflects of course the historically dominant role of coal. But this dominant role will be substantially muted if coal use continues to fall while oil use rises.

1.7 China's Energy Use in an International Context

The broad picture of China's high relative dependence on coal is well-known, but in considering China's policy options going ahead, it is useful to define the comparative pattern of energy use across countries in somewhat more detail. To facilitate international comparisons, here we revert to the IEA data, and to the categories of final energy consumption (the energy consumed within an economic sector, through either the direct consumption of primary fuels such as coal, oil or gas, or through the consumption of secondary fuels such as electricity and heat) and the energy used in the transformation of the primary fuels into sources such as electricity and heat, and into other forms of secondary energy. The total of these two is total primary energy supply (TPES). Here we use these data to compare China's fuel use by type with a benchmark of developed country patterns, by using the OECD countries as a whole. The IEA data underlying the percentages shown in Figures 5-7 are expressed in million tonnes of oil equivalent (mtoe).

Figure 5 Fuel shares of total primary energy supply (TPES), China and OECD, 2014 % of total for each grouping



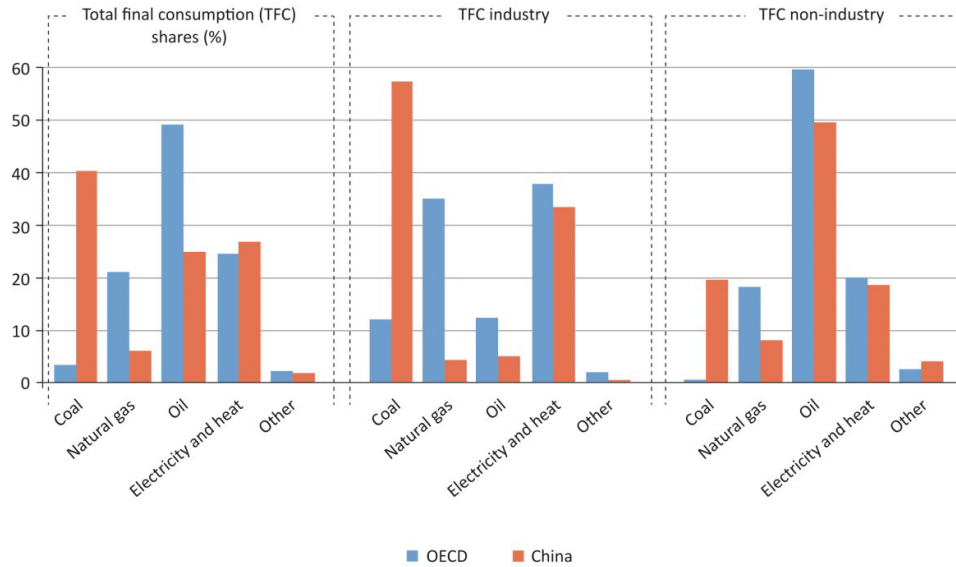
Source: IEA data.

The comparative composition of TPES by fuel for China and the OECD countries as a whole is shown in Figure 5, for 2014. TPES covers the use of primary fuels, so does not include energy use but takes account of the use of primary fuels in generating electricity. The scale of China's dependence on coal is clear (70% of TPES in 2014 as opposed to 20% for OECD countries), and the figure indicates the way in which the heavy emphasis on coal inevitably leads to a reduced role for other fuels. But this reduced role is particularly evident for natural gas relative to oil, and to a lesser extent for non-fossil fuels. While the share of oil in China's coal use is 48% of that for the OECD, the China share of natural gas is only 20% of the OECD share while for non-fossil sources it is 37.4%. Thus the counterpart of China's high coal use is a much lower use of natural gas and still a lower reliance on non-fossil fuels, although this is changing rapidly. Another way of putting this is that, in 2014, China's energy use (TPES) was 56% of that of the OECD, while its use of natural gas was 11.4% of that in the OECD and of non-fossil sources 20.9% of the OECD level.

Figure 6 focuses on the final consumption of energy alone, and hence leaves aside China's heavy reliance on coal for the production of electricity. It thus includes electricity and heat among the fuels consumed, and divides final consumption into the secondary industry sector and other sectors, basically agriculture, services and households. It shows that the direct use of coal is much higher than in the OECD in both sectors – industry coal provides 57.7% of energy use in China against only 12.2% in OECD, while outside industry the relative shares are 19.4% and 0.8%. This is particularly notable as the direct use of coal is more important than its use in electricity generation in terms of emissions of particulate matter, such as PM_{2.5}.

In terms of other fuels, the key messages are the low gas shares in China in both sectors, but particularly in industry, where natural gas provided only 4.2% of industrial energy use in 2014 in China by comparison with 35.6% in the OECD. Outside of industry, natural gas provides less than half the share of energy consumption in China than in the OECD, in spite of rapid growth from a low base in over the past decade. The share of energy use provided by electricity is comparable across China and the OECD in both sectors, and this is true also of the dominant role of oil in non-industrial energy use. But China's use of oil in industry is low, a good deal lower than in the OECD as a whole.

Figure 6 Fuel shares of total final energy consumption, by industry and all other sectors, China and OECD, 2014, % of total for each grouping

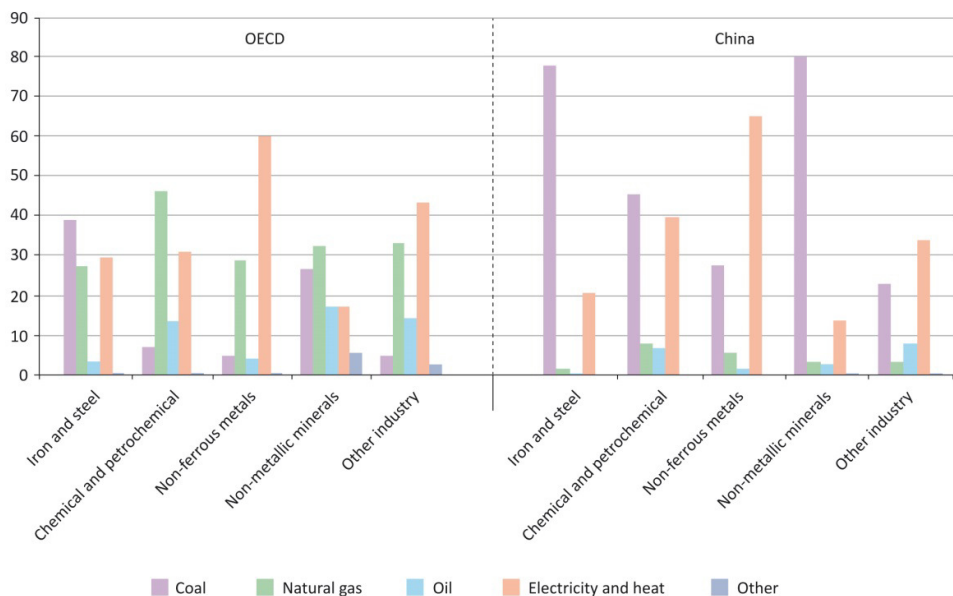


Source: IEA Data.

Given the importance of the direct consumption of energy in industry, and particularly the role of coal here, Figure 7 provides data on the final consumption of energy by fuel in four energy intensive industries, and all other industries. There are differences in industry classifications between IEA and NBS, so that we are only able to provide data for four energy intensive industries (iron and steel, chemicals and pharmaceuticals, non-ferrous metals and non-metallic minerals) and all other industries, in each case based on the definitions used by IEA.

The themes evident in the broader aggregates are repeated at the more disaggregated level, as one would expect. While the use of electricity is broadly comparable across the five industries shown, the big differences are in coal and natural gas. In both iron and steel and non-metallic minerals coal provides about of 80% of China's energy use, more than double that in the OECD (39% and 27% for the two industries respectively). Again this is reflected mainly is gas use, with natural gas use being very low in these industries in China but providing 28% and 33% of energy use respectively in the OECD industries. The chemicals and pharmaceuticals industries show big differences in energy use, again mainly about coal and oil, but perhaps in part reflecting differences in feedstock use. The shares of coal and gas in this industry are 7%/48% in the OECD as opposed to 46%/8% in China, which suggests major opportunities for China to increase gas usage in these industries over the medium term. In non-ferrous metals energy use in both China and OECD is dominated by electricity, but again there is a sharp difference in emphasis on coal or on gas. This is also so in all other industry.

Figure 7 Fuel shares of total final energy consumption, four energy intensive industries and all other secondary industries, China and OECD, 2014, % of total for each grouping



1.8 Conclusions

The central conclusions from this analysis of the patterns of China's energy use are as follows:

- Falling energy intensity not changing structure.*** The sharp slowing in energy use since 2007 has reflected slower GDP growth and continued falls in energy intensity, but little has been achieved in terms of changing the structure of the economy. The share of the six energy intensive industries in GDP rose slightly from 14.1% to 14.3% over 2007-16, while the share of the much less intensive light industry and mining fell from 27.1% to 25.7%.
- Falling intensity: broadly based but especially in the big three.*** The reduction in energy intensity has been broadly based across industries, excluding transport, but has been especially large in the three big energy intensive industries:
 - Energy intensity fell by 50% in these three industries between 2007 and 2016, even as their share of GDP rose, and over half of the overall energy savings over 2007-16 from lower intensity were in these three industries.
 - In secondary industries outside the energy intensive industries, energy intensity fell by 40% over 2007-16 and in the services sector (excluding transport) fell by over 30% over this period.
- Several lagging industries in terms of energy intensity reduction.*** For the transport sector, energy intensity was higher in 2016 than in 2007, although declining by 1.3% per annum over 2013-16. In three of the energy intensity industries (industries 3, 7 and 8 in Table 1), progress has also been slow, with energy intensity falling by only 20% over this nine year period. These four industries need to be the focus of further policy initiatives.

- *Rapid decline in coal share, but continue rise in oil share.* The share of coal in total energy use continues to fall rapidly, and the overall level of coal consumption has fallen over the past three years. As documented in the next section, four interrelated factors have created a powerful engine for reducing coal use, so that this use is likely to continue to fall over the medium term. On the other hand, there has been little abatement in the growth of oil use. This will create problems in terms of air pollution in cities, greenhouse gases and a high import bill for oil.
- *Low gas share of final consumption provides opportunities.* The low share of natural gas in final energy consumption in China relative to the OECD, and especially in particular energy intensive industries, means that China has good opportunities to continue to increase usage of gas rapidly. The combination of market forces and policy support for cleaner fuels is likely to drive continued increases in the share of natural gas in China's fuel use, especially in a regime of lower international gas prices and amply gas supplies available to China, both through pipelines and LNG.
- *Renewables share still lower in China than in OECD, but rising.* On a comparable measurement basis, as provided in the IEA data, the share of non-fossil fuels in TPES was in 2014 much lower in China than in OECD countries as a whole, even though the use of these fuels is rising strongly in China. Addressing the curtailment of wind and solar power generation through the power grid is an important aspect of increasing the role of these sources.

2. Shifting from the Dominance of Coal

Four interrelated factors – the sharp slowing of energy use in the three energy intensive industries, which are heavy coal users, the shift from the direct use of coal to electricity in industry, the shift to non-fossil power rather than coal-fired generation and, within coal-fired generation increased efficiency in the use of coal – have created a powerful engine for reducing coal use. We document in this section this remarkable conjunction of factors.

2.1 Increased Energy Efficiency, Especially in Energy Intensive Industries

Coal is both used directly, as a fuel source in final consumption, or as an input into transformation processes to generate secondary energy sources, such as electricity and heat. Two of these factors relate to the final consumption of coal, and two relate to its input to the generation of power and heat.

The first factor is that China's final coal use is strongly concentrated the three large energy intensive industries in which energy use has been slowing sharply, and in which it fell over 2013-16. Even at a constant coal share in these industries, this means a relative decline in the use of coal across the whole economy. Table 5 provides two items of data relevant to this issue. First, coal has continued to provide about 70% of coal use in the three large EI industries, by comparison with less than 30% in all other industries taken together (lower panel). This constant share means that, as the three industries' share of coal use falls, the share of coal in total energy use falls as a result.

Table 5 Coal consumption as a share of final energy consumption, % of total

	2001	2007	2011	2014
Share of coal consumption across industries (%)				
Three large EI industries	46.6	55.9	62.0	64.0
Other secondary industry	17.3	16.1	14.0	9.9
All other	36.1	28.0	24.1	26.0
Total	100.0	100.0	100.0	100.0
Coal as share of TFC in each industry (%)				
Three large EI industries	68.2	72.2	71.2	69.9
Other secondary industry	53.9	49.3	45.8	33.8
All other	31.2	23.6	21.7	20.4
Total	46.7	46.7	44.5	40.3

Note: Here the three large EI industries are as defined in the IEA data rather than the NBS data, namely iron and steel, chemicals and petrochemicals and non-metallic minerals.

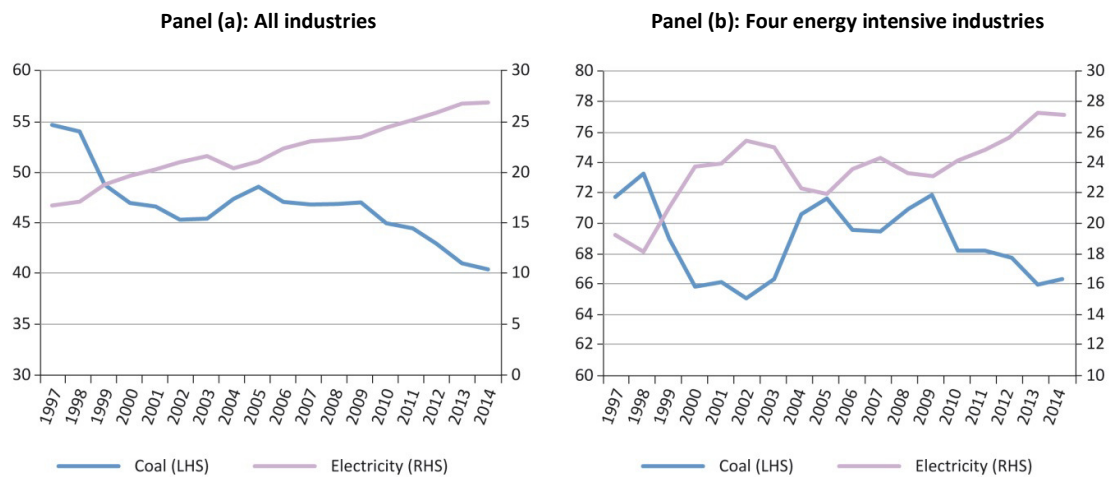
Secondly, while the coal share within these industries has been stable, there has been a strong movement away from coal consumption over 2001-14 in the rest of the economy as a whole. This means that coal consumption has become in the three large EI industries, with these industries providing 64% of national final consumption of coal in 2014. Thus trends in energy use in these industries have a major impact on the overall consumption of coal.

2.2 Reduced Direct Coal Consumption and the Shift to Electricity

In addition to the slowing growth of final energy consumption in industry, there has been a shift to increased direct consumption of electricity in industry, at the expense of coal: over the three years 2011-14 electricity consumption in the economy as a whole grew by 19.0% while coal consumption rose by only 0.5%. As shown in panel (a) of Figure 8, for the economy as a whole this has been a

persistent trend since at least the late 1990s, and underpins the rapid reduction in the share of coal for the economy outside of the three large EI industries shown in Table 5.

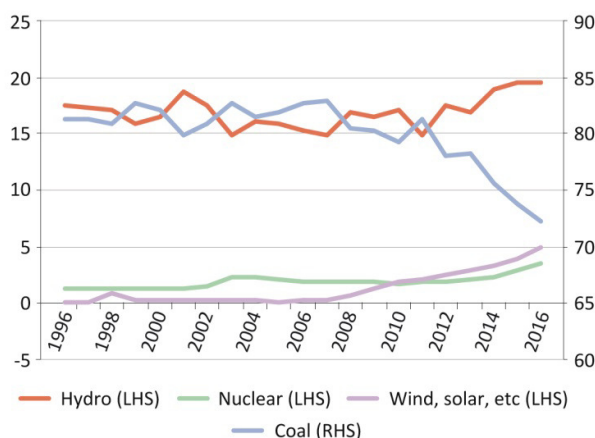
Figure 8 Fuel use in total final consumption, share of total, %



2.3 The Shift from Coal in Power Generation

Thirdly, as is well known, there continues to be a sharp shift from coal to clean fuel sources (hydro, nuclear, wind and solar) in terms of electricity generation. Over the past three years, 2013-16, the annual rate of growth of non-fossil power generation has been 10.2% per annum, while electricity from coal has grown at only 1.5%. This has, of course, been a relatively recent phenomenon, with the downward break in the share of coal-fired generation in total generation only occurring after 2010. This shift to non-fossil fuel sources is likely to continue over the medium term, although there are some signs of a rising share of coal generation in late 2016 and early 2017.

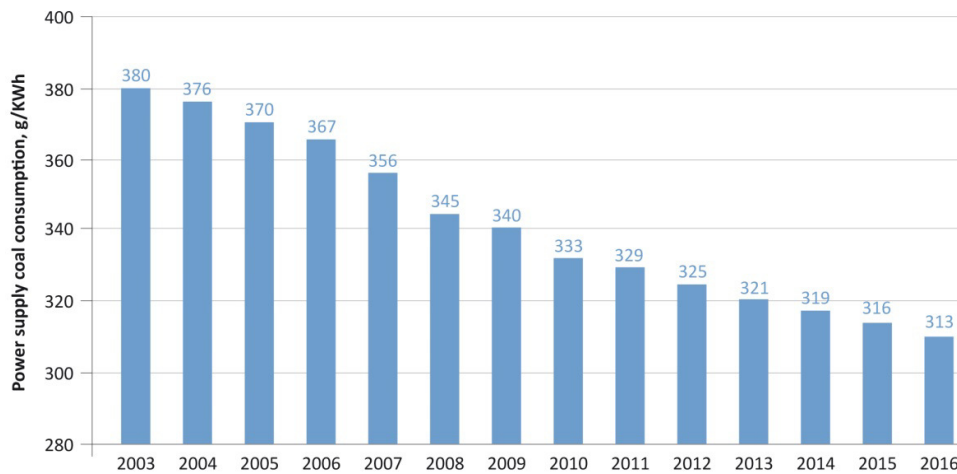
Figure 9 Electricity generation by fuel source, China, 1996-2016, % of total



2.4 Increased Efficiency in Coal Use in Power Generation

Finally, China has also continued to reduce the coal input required to produce a unit of coal-fired power, to the point at which China has become one of the world leaders in this area. Reflecting pressure to close down small, inefficient power stations and a push for over a decade to large, ultra-supercritical plants, net coal consumption per unit of electricity generated has fallen from 380 g/kwh in 2003 to 315 g/kwh in 2015, a fall of 17%.

Figure 10 Coal consumption per unit of coal-fired electricity generation, China, 2003-16, g/kwh



3. Three Specific Challenges Facing China's Energy Sector

3.1 Reducing the Role of Energy Intensive Industries

A key policy focus has been to achieve structural change in the economy to reduce energy use. Here we measure such structural change primarily in terms of the share of the six energy intensive industries in GDP. While the rate of growth of these industries has been falling, this has been broadly in line with the slowing in the overall economy, so that reducing their share remains an elusive goal of policy: the share of these industries in GDP was a little higher in 2016 than in 2007. Two factors work against achieving a reduced share for these industries. One is the tendency for the Government to support growth, in the face of structural changes elsewhere, through monetary policy and infrastructure investment. These stimulate investment in building, construction and heavy engineering, and hence increase the demand for the output of the six industries. The second is lack of any advanced program to reform and stimulate the service industries in China, to grow the industries which will over time employ the human and capital resources currently used in heavy industry.

3.2 Curtailing the Role of Oil in China's Energy Mix

While coal use has been falling, China's oil use has continued to rise unabated, growing by 3.8% over 2013-16 (including by over 5% in 2016) after 5.9% over 2008-13. A significant part of China's oil consumption is in industry, but this component has been growing slowly. Rapid growth continues in the bulk of China's oil use which is in final oil consumption outside of industry, especially the transport sector. With the number of motor vehicles in China increasing rapidly and the continued explosion of air travel, the development of railways systems and the shift to public transport modes in major cities have not been sufficient to curb oil use. If China is to reduce the growth of oil use more extensive programs to increase the fuel efficiency of the existing stock of vehicles may be necessary.

3.3 Achieving an Enhanced Role for Natural Gas

With ample supplies of cheap coal, China's use of natural gas has been, and remains, low relative to advanced countries. This is so even though natural gas consumption has risen by 12.7% per annum over 2007-16. The share of natural gas in final energy consumption in China in 2014 was only about 12% of that in the OECD, with the differential being marked in all of the energy intensive industries. Outside industry the Chinese share of gas in total final consumption is about half of the OECD share. The combination of market forces and policy support for cleaner fuels is likely to drive continued increases in the share of natural gas in China's fuel use, especially in a regime of lower international gas prices and amply gas supplies available to China, both through pipelines and LNG.

Achieving continued rapid growth in natural gas use will require successful completion of the reforms to China's gas market and institutions that is currently underway. China's gas supply chains can be divided into the upstream section (gas production and imports), mid-section (gas transmission) and downstream section (gas uses). The upstream section is dominated by the three oil giants CNPC, SINOPEC and CNOOC. The three oil giants and the gas pipe and transmission corporations at the provincial level are competing in the mid-section (transmission), while the downstream section of the supply chain is shared among the state-owned oil and gas corporations,

foreign companies and private companies. The gas pipe and transmission operators in the mid-section receive a fee (set by the government) for transmitting home-produced gas and imported LNG to the local gas companies and large industrial users in the downstream section. Local gas companies pay city-gate prices for the gas from gas pipeline and transmission corporations (sales prices from gas suppliers plus the transmission fee) and sell gas to the final users at retail prices. There are three retail prices for final users in China: residential retail prices, retail prices for industrial and commercial users (non-residential retail prices) and retail prices for vehicle use (vehicle retail prices). Of the three retail prices, non-residential and vehicle retail prices fluctuate with city gate prices, while residential retail prices have been subsidized by the state. There are thus cross subsidies between non-residential and residential uses for gas in China.

As a result of these features, China's gas market is oligopolistic with serious price distortions. Differential prices are applied to different gas users (residential and non-residential uses), to the 112 billion cubic meters of gas for industrial and commercial users consumed in 2012 (2012 gas consumption) and to the additional consumption since then (incremental gas consumption). There are also variations of gas prices in different regions of China, as the local governments have been responsible for setting local gas prices under the NDRC guidelines.

In March 2014, China introduced a 3-tiered natural gas pricing system (or progressive gas prices) for residential gas users. Under the system, higher retail prices apply to those households which consumer more gas. By August 2014, some cities in five eastern provinces had applied the new pricing system.⁶ The tiered pricing system was aimed at raising the incomes of gas enterprises so as to increase gas supply while at the same time protecting the interest of low income gas users.⁷

In September 2014, the NDRC directed the provincial governments to raise their prices for non-residential gas (wholesale prices) by up to RMB 0.4 per cubic metre,⁸ corresponding to a price jump between 14-25% over the prices in 2013.⁹ This hike came after a similar 15.4% increase for non-residential gas users in July 2013 when the NDRC launched a new pricing mechanism as part of broader energy reforms.¹⁰ The price hikes for non-residential gas caused a backlash from industrial and commercial gas users.

Following plunging oil and coal prices and a backlash from industrial and commercial users, China's NDRC lowered non-residential retail prices in April 2015, the prices for increment gas (gate prices) were reduced by RMB 0.4 m,³ merging with prices for gas at the 2012 consumption level. As a consequence, the dual prices for non-residential gas were replaced by a single price for non-residential gas in some regions. The government also liberalized gas prices for direct trade between gas producers and large non-residential users.¹¹ In November 2015, the NDRC lowered the city gate

⁶ 'NDRC promotes the tiered pricing for residential gas', Newhua News Net, <http://finance.china.com.cn/industry/energy/nyyw/20140808/2598573.shtml>.

⁷ 'NDRC: 3 tiered prices for gas and higher prices for over quote uses', China Economic Net, 21 March 2014, see http://www.ce.cn/cysc/ny/trq/201403/21/t20140321_2527103.shtml

⁸ 'NDRC to raise gas prices for non-residential use by RMB 0.4', China Economic Net, 12 Aug 2014, http://news.xinhuanet.com/yzyd/energy/20140812/c_1112045268.htm

⁹ 'The dilemma for gas price hikes in China: falling oil prices versus high gas prices', Huaxia Energy website, http://blog.sina.com.cn/s/blog_490dbc3d0102v7b2.html

¹⁰ 'China to raise natural gas prices', Xinhua News Net English.news.cn 2014-08-12, http://news.xinhuanet.com/english/china/2014-08/12/c_126863237.htm

¹¹ See NDRC website, http://www.ndrc.gov.cn/zcfb/jd/201502/t20150228_665789.html

prices for non-residential gas by a further RMB 0.7 m.³ Moreover, the government turned the city gate price into a benchmark price, gas suppliers and users were allowed to negotiate a price at or below 120% of the benchmark price, 120% of the benchmark price hence acted as de facto ceiling price for non-residential gas.¹²

To promote market-oriented reform, the Shanghai Oil and Gas Exchange was created in July 2015. The NDRC explicitly requires that the trading of non-residential gas shall go through the exchange, so the prices can be formulated based on the supply and demand under the ceiling price.¹³

The possible impacts of the price reforms include:

- Following lower prices for non-residential gas while residential gas prices kept constant, the cross subsidies between non-residential and residential gas tend to drop. Measured by the ratio of residential to non-residential retail gas prices for possible cross subsidies: 0.7 in China, 2 in EU, 2.5 in USA and 4 in Canada.
- Lower prices of non-residential gas have the effect of increasing gas consumption and raise the ratio of gas in China's total energy consumption.

The reforms to China's gas markets are both ongoing and important, but full documentation and analysis of them is beyond the scope of the current report.

4. Completing the Reform of Power Grids: China and Australia

4.1 The Power System Reforms in China

4.1.1 The power system prior to the 2015 reforms

China's power market has been monopolised by the China Grid and China Southern Grid. The two grids are responsible for power transmission and allocation, and have effectively separated power suppliers from final users. On the supply side, there are around 4,500 power generation plants, consisting of power plants controlled by the big five state-owned power groups (with about 40% of the power generation capacity)¹⁴ and thousands of medium and small power enterprises owned by either the county level governments or private capital. The grids are the sole buyer of the power generated by those plants. On the retail side, there are two groups of power users: non-residential users (industrial and commercial enterprises) and residential users. The former consumes much more power in China than the latter.

A dual system applied to power pricing. China's power market is regulated and supervised by the State Energy Administration under the NDRC. On the supply side, a base price set by the NDRC (plan price) covers 80-90% of the market for power supply, with prices for the remaining 10-20% of the power supply to be discovered through direct negotiations between power plants and large power users. On the retail side, prices for power consumption are also set mainly by the state. There are considerable regional variations in terms of retail power prices. Moreover, residential users have

¹² See NDRC website, http://www.ndrc.gov.cn/zcfb/jd/201511/t20151118_758909.html

¹³ See NDRC website, http://www.ndrc.gov.cn/zcfb/zcfbtz/201502/t20150228_665694.htm

¹⁴ There are about 50 large power plants and stations, with a capacity of 1 GW and over, owned by the central and provincial governments in China.

been cross-subsidized by non-residential users as the latter paying higher prices for their power consumption, even though the costs of power supply to non-residential users are lower.

The system faces numerous challenges. First, the grids have used their monopolistic position to maximize their own interest and profits at the costs of power suppliers and final users. The natural monopoly has given rise to lower efficiency in power transmission, maintenance and allocation, with subsequent higher prices for consumers than otherwise. Second, soft budget constraints and a lack of information about power consumers have made many state-owned power plants less responsive to changes in market conditions, which have resulted in power over-supply. Third, the power prices which have not incorporated environmental costs (costs of air and water pollution and resource use), have impacted negatively on energy saving and development of renewables. Fourth, high curtailment of non-hydro renewable energy power indicates a system failure, technologically and institutionally, to accommodate the rapid growth in renewable energy power. Finally, further efficiency losses occur with cross subsidies between residential and non-residential uses.

4.1.2 The 2015 power system reforms

The government launched a new round of power system reform in March 2015 with the intention to incorporate more market elements into the system and thus to achieve better efficiency. The principle of the reform is so-called “liberalise two ends with controlled middle part”, that is power generation and retail ends will be determined by market force while the grid companies only provide services and charge service fee instead of involving heavily in electricity trading. The reform package includes:

1. **Gradual abolition of the state plan on power generation volume (hours) and establishment of priority generation and consumption schemes.** Prior to the reform, the volume (hours) of power generation was rationed by the government, which could lead to an inefficient allocation of volume, more volume to be allocated to those power plants with low energy use efficiency and high emissions. After the reform, power plants with a low cost structure and high energy use efficiency will be in a position to generate more power. “Implementation Opinions on Orderly Liberalizing Power Generation and Utilization Plans” (November 2015, NDRC and NEA) clearly stated to set up a priority generation/utilization plan system to replace the overall planning system applied for years. Such a partial planning system features with renewable energy power and residential sector enjoy the priority rights in power generation and utilisation; and electricity generation and utilization of non-residential sectors will be determined by market forces through direct trading between suppliers and users and through power trading centres.¹⁵ On 27 November 2016, NDRC issued the Notice on Undertaking Power Supply and Demand Projection and Making Priority Power Generation and Utilisation Plans, marked the priority system is about to implement in 2017¹⁶. Local authorities were required to work in conjunction with relevant departments and firms to form 2017 generation plans for guaranteed renewable energy power and plans to serve for the residential users. Beijing and Guangzhou power trading centres were required to submit prioritized cross-region power transmission pre-scheduling.

¹⁵ NDRC and NEA, <http://www.chinasmartgrid.com.cn/news/20151130/611099.shtml>

¹⁶ See http://www.ndrc.gov.cn/zcfb/zcfbtz/201612/t20161209_829672.html

2. **Market formulated prices for power plants.** Prior to the reforms, power prices (power to the grid) were determined mainly by the government. After the reform, prices are discovered through bidding and negotiations between power plants and final users. The power plants are allowed to sell their power directly to large power users and/or through market trading. According to the official from NDRC, from 2017 onward, newly installed coal-fired generation units generally will be excluded from generation plans, and participate in market trading.¹⁷
3. **Retail power prices liberalized for industrial users, while residential users will still be under government price protection.** Before the reforms, retail power prices were regulated by the state. After the reform, prices for priority planned renewable energy power and for residential users are still controlled by government; while prices for the industrial users and extra planned power (including extra planned renewables) are determined by supply and demand in the market.
4. **Changing role of the grids.** Before the reforms, the grids were the sole buyers and sellers of electricity in China. After the reform, the grids will get their revenue from service fee (ratified by the state and formulated as cost plus reasonable markups). One of the reform measures that stirred up great enthusiasm was that private capital, utility suppliers and power generation plants are encouraged to set up trading companies entering the electricity retail market. With the change of their revenue pattern, increased competition in retail market and social capital allowed to invest in incremental distribution networks, grid companies will have to do better in cost reduction and service quality. It is hoped that the independence of their income from trading, after an interim of a few years, will give grid companies a neutral stand for them to provide fare access for various energy sources, as well as to improve their efficiency including more accurate demand assessment, power storage, network management, etc.
5. **Establishment of power trading platforms to facilitate market orientated power sector reform.** Power trading market is a major component in the new power system and is one of the focuses of current reform. As two of the first batch of supporting documents issued after the announcement of new round of power sector reform, “Implementation Opinions on the Construction of Power Market” and “The Implementation Opinions on the Establishment of Power Trading Organisations and Their Normal Operation” form the principles and implementation direction for trading market construction.¹⁸

4.2 The Process and Progress of the Reforms in China

1. **Pilots to test the reforms.** A pilot on power system reforms was initiated in Shenzhen in November 2014, before the reform was launched in March 2015. The pilot reform was replicated in the western part of Inner Mongolian Autonomous Region (IMAR), Anhui, Hubei, Ningxia and Yunnan provinces in April 2015. Up until November 2016, the reform pilots spread out in 26 provinces (regions and municipalities), stated by an official from NDRC.¹⁹ These pilot reforms are individually and provincially based. The contents of the reform proposals are

¹⁷ See <http://www.chinapower.com.cn/focus/20170120/78628.html>

¹⁸ See NDRC and NEA, http://www.ndrc.gov.cn/zcfb/zcfbtz/201511/t20151130_760016.html

¹⁹ See <http://www.chinanews.com/cj/2016/11-11/8059963.shtml>

different involving grid service cost verification and pricing, retail market operation, incremental distribution networks, and ancillary service market, etc.

2. **Trading platforms.** In March 2016, two national level electricity exchange centres were established, in Beijing and Guangzhou, to handle cross-region power trading and facilitate renewable energy transmission. Beijing Electricity Trading Centre owned by the State Grids is responsible for power trading within the State Grid covering areas.²⁰ Guangzhou Centre controlled by the Southern Grids provides electricity trading services, particularly responsible for executing west-east power transmission strategy set by the central government.²¹ Currently, most provinces and regions have established their local power trading centres for local power trading. 2016 market trading exceeded 1 trillion kwh, accounted for 19% of national power.²² consumption.
3. **Provincial level grid transmission and distribution price reforms.** Currently, all provincial level grid reforms have been approved. According to media, a director from the Pricing Division of NDRC indicated that, verification of the cost of provincial level grids for the first 3-year supervision cycle will be fully completed before the first quarter of 2017, transmission and distribution price reform pilots will cover all provincial level grids and price reform for a few major cross-region grids will be completed in the first half of 2017.²³ In an announcement of the State Grid Corporation early December 2016, 26 provincial level grids (except Xizang) within its service area had all started up their reform in transmission and distribution price.²⁴ As the cost verification is finalised, the grid price formulation process will start. On 22nd December 2016, NDRC issued a notice on “Measure for pricing of power transmission and distribution of provincial level grids (tentative)”.²⁵ It details the composition and calculation of the grid price.
4. **Open up retail market and incremental power distribution business.** By end of 2016, about 6400 sales companies were registered national wide and the first bunch of 105 incremental power distribution pilot projects were approved.²⁶

4.3 The Australian National Energy Market

The National Electricity Market (NEM) in Australia is a regional electricity market for the production and sale of electricity on the interconnected power system in the south and eastern states of Australia including Queensland, New South Wales, Victoria, South Australia and Tasmania. The market began operation in 1998 and has operated continuously since then. The NEM can be described in terms of its structural arrangements, market design and oversight.

²⁰ See <http://www.askci.com/news/chanye/2016/03/01/114530s7wi.shtml> 01-03-2016

²¹ See http://news.xinhuanet.com/finance/2016-03/02/c_128768684.htm and http://www.cs.com.cn/ssgs/hyzx/201603/t20160302_4914748.html

²² See <http://www.chinasmartgrid.com.cn/news/20170310/622498.shtml>

²³ See <http://ex.bjx.com.cn/html/20170221/20967.shtml>

²⁴ See <http://www.chinasmartgrid.com.cn/news/20161207/620794.shtml>

²⁵ NDRC, http://www.sdpc.gov.cn/zcfb/zcfbtz/201701/t20170104_834311.html

²⁶ See <http://www.chinasmartgrid.com.cn/news/20170310/622498.shtml>

4.3.1 Structural arrangements

The NEM is a series of regional markets – each corresponding to the state boundaries. Transmission interconnectors link these regional markets. The market is open to electricity generators whose capacity exceeds 30 Mega Watts. In fact, it is compulsory that their production be sold in the NEM. These generators cannot also own or operate transmission assets. Transmission companies are able to own a limited amount of generation capacity in special circumstances, primarily for the provision of services, such as voltage support, at points on the transmission line. In practice the five transmission companies that own and operate transmission assets in the NEM own almost no generation.

Transmission is also separated from distribution although the boundary between distribution and transmission is defined differently in the various NEM regions.

The business of retailing electricity is legally separated from distribution and in most NEM regions is undertaken by businesses that are completely independent of the distributors.

Generators that offer production for sale in the NEM do not self-dispatch their plant. Instead their plant is operated by the Australian Energy Market Operator (AEMO) and this operation, in normal conditions, is the outcome of five minute final price constrained optimisation auctions based on market bids (this is described further below).

AEMO also operates the power system and in one NEM region is responsible for planning the development of the transmission system. AEMO does not own any transmission or generation capacity. AEMO is also the operator of the electricity market in Western Australia, which is in all other respects separate from the NEM.

Rules for the operation of the NEM are administered by the Australian Energy Markets Commission (AEMC). Market participants, customers and governments can propose changes to these rules and the AEMC will assess their proposal on the basis of whether they estimate that these changes will better serve the long term interest of consumers.

The Australian Energy Regulator (AER) enforces the rules and reports when market prices exceed specific thresholds.

Electricity retailers and a few large customers buy from the NEM by making payments to AEMO for the quantity of electricity they purchase in each half-hourly Settlement Period.

4.2.2 Market design

The NEM is a mandatory final price energy-only market. The mandatory and energy-only aspects are unusual in comparison with electricity markets elsewhere (almost all electricity markets are not mandatory and provide compensation also for making capacity available).

Prices in the NEM are calculated in five-minute trading intervals, and are specified at Regional Reference Nodes, each of which are located at the capital city in each of the NEM regions. These prices are, conceptually, the change in the total cost of production in order to deliver the last Mega Watt at the Regional Reference Node in each state.

AEMO calculates this price using a constrained optimisation calculation, where the constraints are based the physical parameters of the power system including the impedance characteristics of the various transmission lines, and operational and power system security constraints.

A half-hourly Settlement Price is calculated as the average of the six five-minute Trading Prices. Generators receive the Settlement Price and retailers and NEM-connected very large customers pay the Settlement Price adjusted for the marginal value of the transmission losses at the point at which the sell to/buy from the market.

Trading Period and Settlement Period prices are capped at a maximum of \$14,000 per Mega-Watt hour, and a minimum of -\$1000 per Mega-Watt hour. The NEM is by far the most volatile electricity market in the world with higher market price caps than in any other market. In addition to the market price cap, there is a Cumulative Price Threshold that caps the cumulative average prices over a specified period.

In addition to the main market for the sale and purchase of electricity, there are a number of “ancillary services” markets for the sale of services to rapidly increase or lower production (or demand) in order to ensure that the frequency of the power system remains within tight limits around the 50 Hertz standard.

The prices in the NEM regions are typically similar to each other as long as the transmission systems remain unconstrained as is usually the case. Market participants can purchase Interconnector Settlement Residues (the difference in the prices in the regional markets multiplied by the volume of electricity that flowed over the interconnector) by participating in periodic auctions for the purchase of these settlement residues. This allows participants to at least partly hedge the price risks they bear when they sell to customers in one NEM region but buy from generators in another.

Market participants are free to contract around the prices determined in the NEM, to effectively swap spot prices determined in the NEM for the prices specified in the contracts. The contracts are arranged bi-laterally, over the counter by brokers or through the Australian Stock Exchange (ASX). The greatest volume of contracts is traded through the ASX. The most traded contracts on the ASX are calendar or financial year “base-load” contracts that specify one MWh for every hour of the year. Other contracts include “peak-load” contracts for one MWh during the day time. Cap contracts to hedge spot prices above \$300 per MWh are also common. Contract market liquidity diminishes beyond a year ahead and hedge market liquidity in some NEM regions – South Australia and Queensland in particular – is extremely limited. This reflects a high level of concentration in the supply-side of the market.

4.3.3 Outcomes

The NEM has, until recently, been considered to have been one of the more successful developments in the Australian electricity market. It has delivered relatively stable prices and the market and power system has generally been operated to a high standard. The governance of the industry in respect of the operation of its rules, and changes to those rules affecting the NEM has generally been uncontentious.

The NEM has adapted to some changes and various issues have risen and slipped in importance over time. In its early life, the number of regions was reduced to share hydro capacity previously between two regions.

Other earlier concerns include the selection of zonal rather than nodal markets (the latter being common in electricity markets in the United States). Proponents of a nodal market suggested that zonal structures led to incorrect prices and stifled competition between generators. These concerns remain but no longer attract attention by authorities or market participants.

Early concerns about the inability to hedge risks of trading across regions have likewise not been resolved but instead market participants seek to procure the electricity they sell in one region from production in that region.

An enduring concern in the NEM has been the incentive that generators have to exercise market power by withdrawing capacity from the market and thereby forces prices higher. At times, relatively small amounts of capacity withdrawal can have a significant impact on market prices. The AER has monitored this and found many instances of this. However, this behaviour has not been penalised.

Most recently, authorities are considering whether to reduce the Settlement Periods from 30 minutes to 5 minutes so that responsive generation and demand, and batteries, are more highly valued and competition in the provision of market stability services is enhanced.

Also recently the expansion of renewable generation, much higher gas prices and the withdrawal of coal generation from the market has led to extremely volatile, and generally much higher prices. A topic of contemporary debate is whether the market should be reformed to also compensate producers for being available to produce.

In summary, while there has been a continual stream of dissent about the effectiveness of the NEM since its creation, its ability to deliver reasonable prices has kept this dissent in check for much of the time since the market was developed. However, the very large increases in prices over the last year combined with power failures in some regions have damaged confidence. Some state governments and the Commonwealth Government are now intervening in the market to invest in generation, control the operation of market and set prices. This reflects a pervasive crisis of confidence in the governance of the market and the influence of the dominant vertically integrated generator-retailers.

4.4 China's Reforms Far from Completed

From the current reform set-outs and progresses overall, a few challenges may have impact on the success of the reform. First, at the moment, the system reform is at a trial and error stage, different places run different reform programs based on individual cases. When a unified operational model was chosen and promoted, the Central government's ability in coordination and correction will under test. Second, state control on the volume and prices of power generation has been replaced to some extent by local government control in some pilot regions. Such change over may enhance local protection. For example, with the pilot on Yunnan Province, after the central NDRC withdrew from the market, the Provincial Bureau of Industry and Information and Technology stepped in to control the volume and prices for hydro power stations in the province. Third, as grid companies are allowed to set up sales companies and operate distribution networks (although with some restrictions) and as they have technical and information advantages over other market players, they may remain responsible for the allocation of electricity across the country. Therefore, how to effectively regulate grid companies' behaviour and give them incentives to participate in the reform remains a challenge.

Drawing from Australian's experience, China's reform is far from completed. The gaps we may find are at least in four areas. First, clear boundaries of market participants. In China, boundaries of market participants in each market segment are not clearly defined. For instance, although China has achieved the separation of generation plants and transmission entities from previous reform in 2002, the separation of transmission and distribution and the separation of distribution and retailing are somewhat touched but not in a big way. Competition is introduced in distribution and retail market in this round of the reform, but grid companies' involvement in transmission, distribution and retailing is not affected primarily. Thus, independence of market participants could not be assured and hence conflict of interests and loss of efficiency may occur.

Second, established institutional structure. Through the description above, a structured system is established in Australia and helps in making a smooth market operation. Each administrative body has its own defined roles in the market this leads to better problem solving.

Third, an indiscriminate and unified market. Regional markets are interconnected in Australia and the dispatching of power by AEMO through the bidding process makes the power source and type irrelevant in the trading, thus assuring the best priced for power transmitted. Cross region transmissions do present as a problem but relatively easy to solve in Australia. In China, however, this is a big issue and needs to be properly addressed. Because of the geographic concentration of generators in a few regions and load centres in other regions make the long distance transmission requirement high, at the same time local governments play major roles in regional power generation plans which resulted in regional barriers or local protection (see Appendix). Thus to overcome the technical issues on long distance transmission as well as break local barriers requires are factors should be considered and incorporated in the design of the system.

Fourth, Australian recent experience of price volatility with the expansion of renewable energy generation, high gas price and the withdrawal of coal generation from the market should concern Chinese policy makers as these factors are all existing in China.

4.5 Analytical Projections of China's Energy Use to 2025

In this section, we report the results of projections of China's energy use, in total and by industry, based on the analysis of trends in value added and energy use by industry. As noted earlier, this analysis, and hence these projections, use NBS data on energy consumption and our data on real value added by industry, constructed on the basis of NBS data. As a result these projections do not distinguish types of energy use (whether final consumption or transformation) nor the composition of energy use by fuel. We have built a simple model, based on the IEA data, to take these aggregate projections and break them down by type of energy use and fuel. The results of this work will be reported at a later date.

Table 6 Assumptions for energy use projections, 2017-2025

	Base Case	Policy Case 1 – Structural change	Policy Case 2 – Structural change and continued rapid EI reductions
Rationale	Slowing GDP growth affects all industries equally; long term reductions in EI continued, but at a slower rate	Significant slowing in growth in the six energy intensive industries; EI assumptions as in base case	Incorporates both structural change and more rapid reductions in energy intensity
Aggregate GDP growth	Declining steadily from 6.7% in 2016 to 5.7% by 2025	As for base case	As for base case
Industry structure	Industry growth rates of value added adjusted pro-rata to slowing GDP growth	Growth rates for the six EI industries reduced by 10% per annum over 2017-2025.	As for policy case 1
Energy intensity	Industry reduction in EI declining to 75% of 2007-16 rate per annum by 2021; then held at 75%. For transport these are applied to the 2013-16 change.	As for base case	Industry reduction in EI held at 100% of 2007-16 rate to 2025; for transport at 100% of 2013-16 rate.

The assumptions underlying these projections are provided in Table 6, and the results are summarised in Table 7 and Figures 11 and 12. Three cases are studied. In all cases aggregate GDP growth is assumed to slow gradually from 6.7% in 2016 to 5.5% by 2025. In the base case this slowing of growth is distributed across industry growth pro-rata, so that industry-specific growth rates fall by the same proportion as the aggregate rate. We also assume that reductions in within-industry energy intensities continue, but at a slower rate than over 2007-16. These rates of reduction are assumed to drop gradually to 75% of the 2007-16 rate by 2021, and to hold that proportion to 2025. Because of the distinctive behaviour of energy intensity in transport (which rose by 0.7% per annum over 2007-16 but fell at 1.3% per annum over 2013-16) we apply these parameters to the 2013-16 growth for transport.

Policy case 1 involves no change in aggregate GDP from the base case, but incorporates a significant degree of structural change in terms of a reduced role for the six energy intensive industries. Specifically, the growth rates of these six industries are reduced by a cumulative 10% each year after 2017, for each industry, and hence fall to only 20% of their base case rate by 2025. The upshot of this is the share of the six industries in total GDP falls from 14.3% in 2016 to 11.4% in 2025. Policy case 2 adds to policy case 1 more rapid rates of reduction in industry-specific energy intensity than in the base case, specifically that for all industries other than transport continued firm policy enables the economy to continue to achieve 100% of the reduction rates over 2007-16, and for transport 100% of the rates over 2013-16.

Figure 11 Growth rates of energy consumption, China and the OECD, 1970 -2025, 5 year moving averages, % per annum

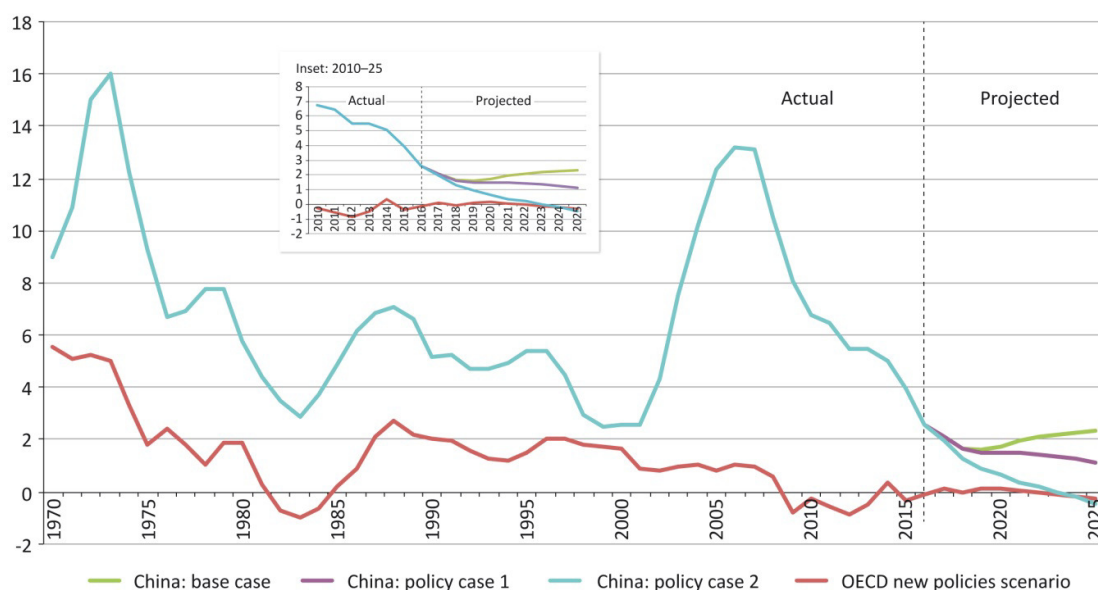


Figure 11 shows the outcomes of the three projections cases, and of a simple projection of overall OECD in conjunction with historical data back to 1970. Each data series shown is the average annual rate of growth in energy use over the five years to the year shown. The figure shows the long run trend to lower growth in energy use in the OECD, from about 5% in 1970 to zero or negative at the present time. It also brings out the explosion of energy use that took place in China after its entry into the WTO in 2001, but also the way in which policy change and other factors back to a much more modest rate of growth consistent with an underlying trend excluding the post-2001 acceleration.

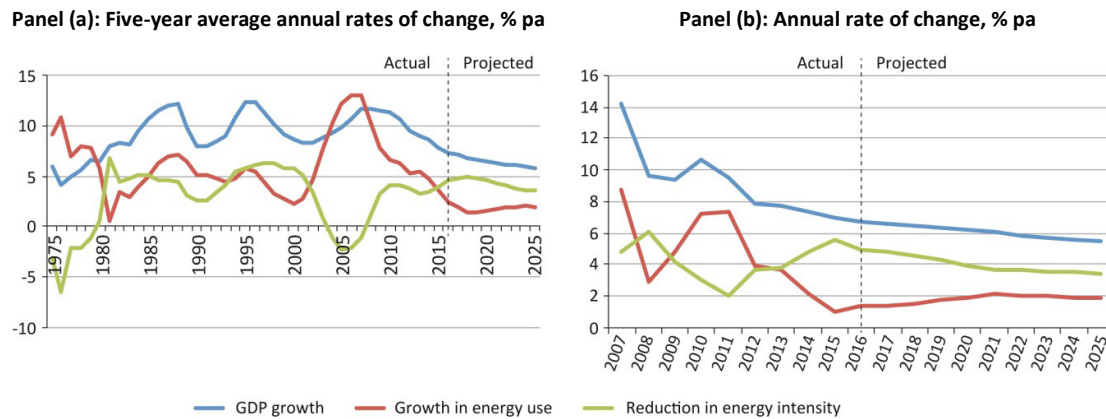
Table 7 Projected growth rates of energy use, aggregate and by industry, China, 2016-25, three scenarios

	Average annual growth rate	Average annual growth rate 2016-2025, % pa		
	2007- 16 (% pa)	Base case	Policy case 1	Policy case 2
Primary	1.8	0.4	0.4	-0.3
Mining	3.8	0.6	0.6	-0.2
Petroleum, Coking and Nuclear Fuel	4.8	3.8	1.6	1.3
Chemical Material and Product	4.2	1.9	-1.0	-2.4
Non Metallic Mineral Product	2.2	-1.3	-3.6	-5.5
Ferrous Metals	0.8	-2.0	-3.1	-4.3
Non Ferrous Metals	6.8	4.0	0.8	-0.2
EGW	4.6	1.1	0.1	-0.2
Other industry	2.2	0.6	1.1	-0.1
Construction	7.3	2.6	2.6	1.8
Transport, etc.	6.6	3.5	3.5	3.2
Wholesale and Retail Trade	6.4	2.5	2.5	1.7
Other Services	7.0	4.3	4.8	4.2
Residential	5.1	3.5	3.5	3.1
Total energy consumption	3.8	1.7	0.9	0.1

These projections imply, for the base case, an average rate of growth of energy use of 1.7% over 2016-25, although the projected rate rises to over 2% after 2000, as the extent of the reduction in

energy intensity declines. Achieving real structural change would reduce the average projected rate of growth by nearly one percentage point, while further reductions would be achieved if both rapid structural changes and continued reductions in energy intensity at 2007-16 rates to 2025 were achieved.

Figure 12 Growth in GDP and energy use, and change in energy intensity, China, actual 1975-2016 and projected 2016-25



These projections indicate that China is likely to remain in a period of low energy growth through to 2025, with growth in energy use in the base case being less than 2% per annum over 2016-25. This result assumes the continuation of the strong policy settings that are currently in place. But if, as a result of market forces or further policy impacts, the role of the energy intensive industries is reduced, this will lead to a further slowing of energy, as will maintaining the rates of reduction in emissions intensity evident in recent years. Slow growth in energy use will assist China to address the issues of pollution and environmental damage, especially in the context of a rapid decline in the share of coal. But it is also likely to make the problems of overcapacity in energy production and the costs associated with stranded assets more acute, as well as making the building of more efficient, and market-based institutions more complex.

It is to be noted that energy use in many advanced economies has been falling in recent years, and for the OECD region as a whole, total primary energy consumption was 3% lower in 2015 than in 2005. China remains a developing country with a strong rate of economic growth, and will see continued growth in energy use for the foreseeable future. But as its economy modernizes, adopts more efficient technologies and becomes increasing service oriented, this growth will moderate further.

5. Conclusions and Policy Implications

The following is a brief summary of the conclusions of this report:

- Reducing the rate of growth of energy use to about 1.5% since 2013 is a major achievement, and low rates of growth in overall energy use should continue to 2025.
- The change from rapid growth to decline in coal use, driven by the four factors outlined, is a massive change, and the decline is likely to continue.

- Structural change away from the six energy intensive industries has not occurred; it needs, inter alia, more pro-active policies to support services.
- Containing oil use (especially in transport) is critical, but requires more action on the current vehicle stock, beyond encouraging electric vehicles and modal change.
- Gas remains a major opportunity, both in industry and residential, especially with lower global gas prices and ample supplies for China.
- An efficient, market-based power network is urgently needed to facilitate the energy transition to renewables. Much work is underway to implement reform and to provide the required infrastructure.
- While the NDRC/NEA document is an impressive plan, the targets are more modest than can be achieved, and they need to be achieved to meeting China's energy and pollution challenges.

Appendix 1. Issues Related to High Curtailment of Wind and Solar Energy Power

A1.1 General Picture of Current Renewable Energy Power

Thermal power generation investment is still on the rise compared with that of renewables. Figures A1 and A2 below show a clear increase from 2012 both in terms of thermal power generation capacity under construction and in investment value. The closure of the thermal capacity in comparison with the increase of the thermal capacity is minimal. Only hydro power capacity construction has a somewhat significant increase in 2015, and Figure A2 shows that investment in thermal has been stable, while investment hydro, wind and nuclear energy experienced reductions after 2012.

Figure A1 Major power groups' generation projects under construction, year-end, 10 thousand kw

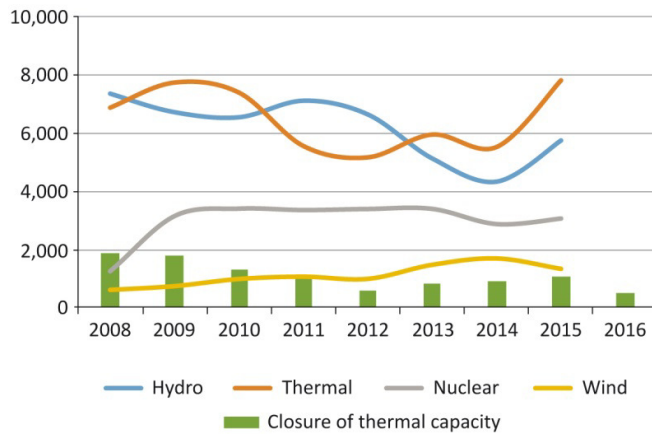
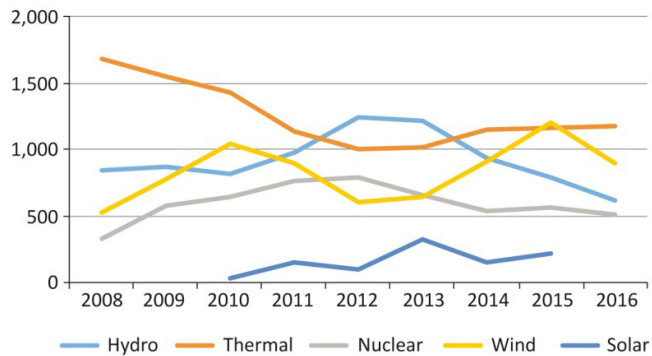


Figure A2 Completed power generation investments, 100 million yuan



Source: CEC Power Industry Annual Statistics, various issues 2009-2016.

High growth of installed capacity in resource rich regions with limited local power consumption.

The growth of installed renewable energy power capacity in the resource rich regions has by far been exceeding the growth of local electricity consumption (Table A1). According to the NEA Northwest Regulatory Bureau, in 2016, Ningxia's maximum load of power consumption was 11.52 million kw with an installed renewable generation capacity of 13.37 million kw; in Gansu, the maximum load of power consumption was 13.39 million kw with an installed renewable power capacity of 19.57

million kw; and in Xinjiang, the maximum load of power consumption was 26.03 million kw with an installed renewable power capacity of 24.77 million kw. Recent economic slowdown has worsened the demand situation, while generation capacity growth is still rising. According to Chinese Wind Energy Association's data obtained from equipment suppliers, the installed, but yet to be grid connected, capacity is 13% higher than the grid connected capacity stock figure reported in NEA's data, and the increase of that capacity in 2016 alone was 20% higher than the NEA figure.²⁷ This indicates a larger difference between what is installed and can be consumed locally than the officially accepted data, and the pressure to resolve such mismatches apparently is very high.

Table A1 China renewable power capacity and consumption by province

	Stock of installed wind power capacity 10 th kw		Wind power generation 100 mil kwh		Renewable electricity consumption including hydropower 100 mil kwh	Share renewable power consumption in total local electricity consumption %
	2016	2015	2016	2015	2015	
Beijing	19	15	3	3	81	8.5
Tianjin	29	29	6	6	63	7.8
Hebei	1188	1022	219	168	260	8.2
Shanxi	771	669	135	100	152	8.8
Shandong	839	721	147	121	270	6.4
Inner Mongolia	2557	2425	464	408	354	13.9
Liaoning	695	639	129	112	197	9.9
Jilin	505	444	67	60	105	16
Heilongjiang	561	503	88	72	119	13.7
Shanghai	71	61	14	10	419	29.8
Jiangsu	561	412	98	64	599	11.7
Zhejiang	119	104	23	16	658	18.5
Anhui	177	136	34	21	157	9.6
Fujian	214	172	50	44	504	27.2
Jiangxi	108	67	19	11	266	24.4
Henan	104	91	18	12	261	9.1
Hubei	201	135	35	21	616	37
Hunan	217	156	39	22	672	46.4
Chongqing	28	23	5	3	432	49.4
Sichuan	125	73	21	10	1575	79.1
Shaanxi	249	169	28	28	163	13.4
Gansu	1277	1252	136	127	466	42.4
Qinghai	69	47	10	7	461	70
Ningxia	942	822	129	88	137	15.6
Xinjiang	1776	1611	220	148	362	22.6
Xizang	1	1	0.1	0	38	84.4
Guangdong	268	246	50	41	1758	33.1
Guangxi	67	43	13	6	770	57.7
Hainan	31	31	6	6	26	9.8
Guizhou	362	323	55	33	450	38.3
Yunnan	737	412	148	94	1233	85.7
National total	14864	12934	2410	1863	13625	24.5

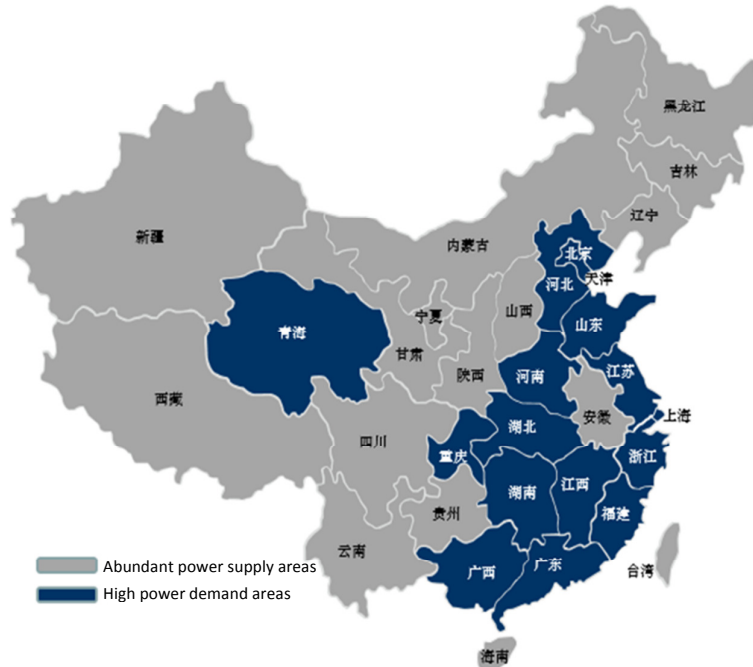
Sources: NEA, http://zfxgk.nea.gov.cn/auto87/201608/t20160823_2289.htm?keywords=NEA, http://www.nea.gov.cn/2017-01/26/c_136014615.htm and http://www.nea.gov.cn/2016-02/02/c_135066586.htm.

Generation centres are far from load centres. Concentrated geographical distribution of renewable power generation centres is far from load centres (Figure A3), which makes the power generation heavily reliant on outbound channels to other regions. Limitation of grid capacity for power delivery to other regions and local load regulation capacity has been one of the major issues often mentioned

²⁷ Chinese Wind Energy Association, 2017 <http://ex.bjx.com.cn/html/20170217/20940.shtml>

by Northwestern officials.²⁸ At the recent People's Congress in March 2017, when interviewed by media reporters, Mr Zhou, Director of Gansu Development and Reform Commission said that Gansu at the moment has to depend on two UHV outbound transmission lines which are also shared with Qinghai and Xinjiang to deliver between 3.3-4.3 million kw power to other provinces.²⁹ Compared with Gansu's current renewable installed capacity of nearly 20 million kw mentioned above, the delivery channel is obviously very limited in Gansu's case. Same concerns were also raised by Xinjiang's representative at the same Congress.³⁰

Figure A3 2014 China power supply abundance and short of supply provinces and regions



Source: ShenWan Securities Research, <http://www.hibor.com.cn>.

High geographical concentration of wind and solar curtailment regions. Tables A2-A4 show the curtailment situation of wind and solar power. High wind and solar power curtailment regions are heavily concentrated in a few areas. For instance, wind power installed capacity in Inner Mongolia accounted for over 17% of national total wind power capacity, wind power generation accounts for over 20% of that in national total, with a curtail rate of 25% in total curtailment in 2016. Gansu and Xinjiang also have a very high proportion of national wind power installed capacity and curtailment.

²⁸ NEA Northwest China Energy Regulatory Bureau, 2017, <http://xbj.nea.gov.cn/website/Aastatic/news-176162.html>.

²⁹ 2017, <http://money.163.com/17/0311/07/CF7TF7VI002580S6.html>.

³⁰ 2017, <http://money.163.com/17/0311/07/CF7TF7VI002580S6.html>.

Table A2 2015 and 2016 wind power installed capacity and operation by regions that have curtailment

	Change of installed capacity 10 th kw		Stock of installed capacity, 10 th kw		Generation, 100 mil kwh		Curtailment 100 mil kwh		Curtailment rate%		Utilisation hours	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Hebei	109	166	1022	1188	168	219	19	22	10	9	1808	2077
Shanxi	214	102	669	771	100	135	3	14	2	9	1697	1936
Inner Mongolia	407	132	2425	2557	408	464	91	124	18	21	1865	1830
Liaoning	30	56	639	695	112	129	12	19	10	13	1780	1929
Jilin	36	61	444	505	60	67	27	29	32	30	1430	1333
Heilongjiang	49	58	503	561	72	88	19	20	21	19	1520	1666
Shaanxi	39	80	169	249	28	28	0	2	0	7	2014	1951
Gansu	245	25	1252	1277	127	136	82	104	39%	43%	1184	1088
Ningxia	404	120	822	942	88	129	13	19	13%	13%	1614	1553
Xinjiang	842	85	1611	1776	148	220	70	137	32%	38%	1571	1290
Yunnan	90	325	412	737	94	148	3	6	3%	4%	2573	2223
National total	3297	1930	12934	14864	1863	2410	339	497	15%	-	1728	1742

Sources: NEA, http://www.nea.gov.cn/2017-01/26/c_136014615.htm and http://www.nea.gov.cn/2016-02/02/c_135066586.htm

Table A3 2015 and 2016 solar power installed capacity by regions with curtailment

	Installed capacity 10 ts kw		Power generation 100 mil kwh		Utilisation hours		Curtailment 100 mil kwh		Rate of curtailment %	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Shaanxi	-	278.4	-	19.65	-	1459	-	1.4	-	6.9
Gansu	-	680.1	-	59.3	1061	1043	26	25.8	31.0	30.5
Qinghai	-	680.9	-	59.48	-	1428	2	8.1	3.0	8.3
Ningxia	-	500.4	-	52.38	-	1338	3	4.0	7.0	7.2
Xinjiang	-	597.6	-	66.35	1042	974	18	31.1	26.0	32.2
Subtotal	-	3037.4	-	287.17	-	1151	49	70.4	-	19.8
National total	4318	7742	392	662	1133	-	-	-	-	-

Sources: NEA, http://www.nea.gov.cn/2017-02/04/c_136030860.htm, http://www.nea.gov.cn/2016-02/05/c_135076636.htm, and Northwest Energy Regulatory Bureau of NEA, <http://xbj.nea.gov.cn/website/Aastatic/news-176162.html>.

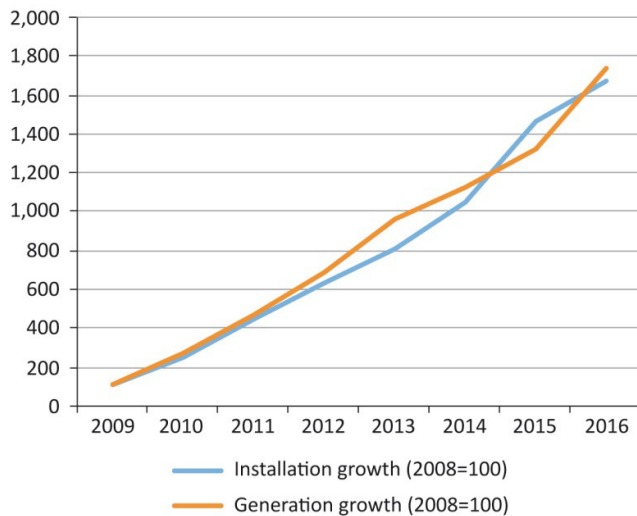
Table A4 Regional concentration of wind power installed capacity, generation and curtailment, share in national total %

	Installed capacity		Generation		Curtailment	
	2015	2016	2015	2016	2015	2016
Hebei	7.9	8.0	9.0	9.1	5.6	4.4
Shanxi	5.2	5.2	5.4	5.6	0.9	2.8
Inner Mongolia	18.7	17.2	21.9	19.3	26.8	24.9
Liaoning	4.9	4.7	6.0	5.4	3.5	3.8
Jilin	3.4	3.4	3.2	2.8	8.0	5.8
Heilongjiang	3.9	3.8	3.9	3.7	5.6	4.0
Shaanxi	1.3	1.7	1.5	1.2	0.0	0.4
Gansu	9.7	8.6	6.8	5.6	24.2	20.9
Ningxia	6.4	6.3	4.7	5.4	3.8	3.8
Xinjiang	12.5	11.9	7.9	9.1	20.6	27.6
Yunnan	3.2	5.0	5.0	6.1	0.9	1.2
Total	77.1	75.7	75.4	73.2	100.0	99.8

Sources: VISES compiled from NEA 2016 Wind Power Grid Connection and Operation Report, http://www.nea.gov.cn/2017-01/26/c_136014615.htm, Jan, 2017 and http://www.nea.gov.cn/2016-02/02/c_135066586.htm, Feb 2016.

Consumption growth is not high enough to meet with the expansion of installed capacity. Figure A4 takes wind power as an example and shows robust and compatible growth rates of both installed wind power generation capacity and generation volume over time. That is the grid capacity expansion generally has kept up with the increased capacity. However, the existence of high curtailment tells that the generation or consumption growth has never been high enough to meet with the increased capacity.

Figure A4 Growth of grid connected installed wind power generation capacity and that of wind power generation



Source: VISES compiled from CEC <http://www.cec.org.cn/guihuayutongji/tongjixinxi/niandushuju/>

A1.2 Technical Issues Versus Institutional Issues with High Wind and Solar Energy Power Curtailment

The tables and figures shown above imply that technically there are reasons to be blamed for the high curtailment of wind and solar energy power, for instance not enough transmission channel grids for the cross-regions distribution, not enough means of storage capacity to regulate peak load due to the nature of wind and solar energy, etc. However, the following two institutional factors have a great impact on the curtailment of renewable energy power and should not be ignored.

Regional barriers. Local protection of coal-fired generation is a typical case in cross-regional power transmission. Behind the background of slow growth in power consumption, increasing the use of renewable energy power means a cut-down of their local coal-fired power, and this has given rise to local protection. Some local governments set limits on volume and price for cross-region power purchase and restrict firms to purchase from other regions or provinces.³¹ Some local governments required wind generation units to compensate for coal-fired units in exchange for generation volume, stopping wind power units to operate, and various other measures.³² It was reported in the media that 12 renewable energy firms in Gansu participated in the winter heating period trade last November with zero price to get a total of a 1105 million kwh contract in exchange for operation.³³ This means firms only rely on government subsidies to survive.

More focus on investment than demand. Investment planning has been playing an important role in China's economic growth and is a core part of the five-year plans, however the scope of demand has rarely been an integral part of the planning. Investors seem also more responsive to investment incentives. Interesting enough, in the case of wind power capacity development, investment growth had hardly been curbed within the expected range in five-year plans. Table A5 depicts the differences between targets and the results for the 11th and 12th Five-Year plan periods. A more recent example

³¹ See <http://guangfu.bjx.com.cn/news/20170301/811216-2.shtml>

³² See http://www.meidianwang.com/MD_HotNews/HotNewsDetail/2049.html

³³ See <http://news.bjx.com.cn/html/20161208/795094.shtml>

is the capacity expansion rush which occurred in 2014-15 in wind power and 2016 for solar power when the government announced a drop of wind and solar power grid feed-in price. This might happen again in 2017 as a new round of price drop was announced by the government at the end of 2016. The dynamics of the relationship between power capacity, consumption and grid capacity expansion, has been not well coordinated, and resulting in a high curtailment rate of wind and solar energy power.

Table A5 Planned targets and actual results for renewable energy power capacity investment, 10 thousand kw

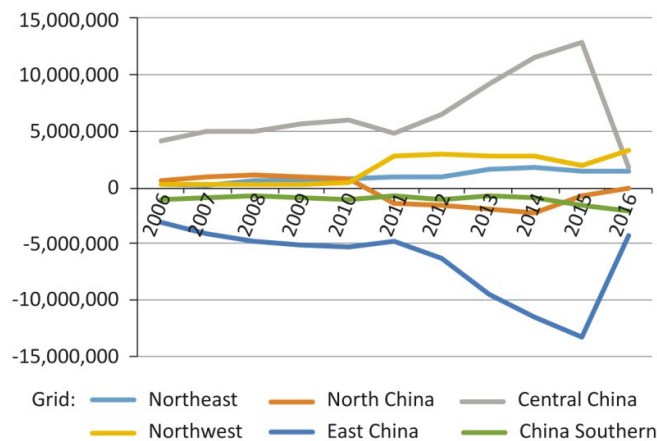
	End of the starting year	End of the ending year	Target
11th Five-Year plan (2005-2010)	2005	2010	
Hydro power (10 th kw)	11739	21605	19000
Wind (10 th kw)	126	3100	1000
Solar (10 th kw)	7	80	30
12th Five-Year plan (2010-2015)	2010	2015	
Hydro power (10 th kw)	21606	31954	29000
Wind (10 th kw)	3100	12900	10000
Solar (10 th kw)	80	4318	2100

Source: NDRC website, http://www.gov.cn/gzdt/2008-03/18/content_923497.htm, http://www.gov.cn/zwqk/2013-01/23/content_2318554.htm

A1.3 Recent Policy Development and Reforms in the Promotion of Renewable Energy Power Consumption

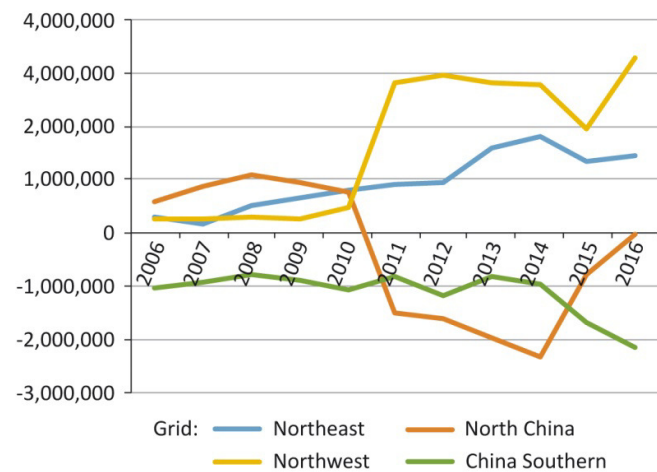
Cross-region power transmission showed pattern of change. Figure A5 gives us some ideas of cross-region power transactions in the past few years. It depicts regional grids annual net power delivery (sending) volumes, where lines below zero imply the provinces covered by their respect grids are the net power receiving regions and those above zero are the net sending regions. From 2010, China's eastern, northern and southern grid regions are net recipients, while northeastern, northwest and central regions are net senders. This pattern has somewhat changed in the last couple of years. A big volume slide in the Central China grid in 2016 is mirrored by a same scale of decrease of the take-in volume in the East China Grid region, and that is consistent with the much slower economic growth rate. The North China grid region moved from a net receiving region to a region almost self-sufficient from 2014 to 2016. Among net power recipients, only the China Southern Grid kept a steady growth in taking in power from other provinces, and only the Northwest Grid achieved expansion in sending power out to other regions. In Figure A6, by excluding the Central and East China grids from Figure A5, we could scale up the picture and this allows us to have a clearer picture of the other lines. The most apparent change shown in this figure is the increase of sending volume by the Northwestern Grid region in 2016 and a relatively steady expansion of take-in power from other regions by the China Southern Grid region. This indicates more wind and solar energy power were sent out from the northwestern region and more hydro power consumed by Southern Grid regions. Unfortunately, constrained by data, we could not have a breakdown by energy types to understand more about the details of the cross-region power transmissions.

Figure A5 Cross-regional power transmissions by grid regions, 10 thousand kwh



Source: Wind Info, compiled by VISES.

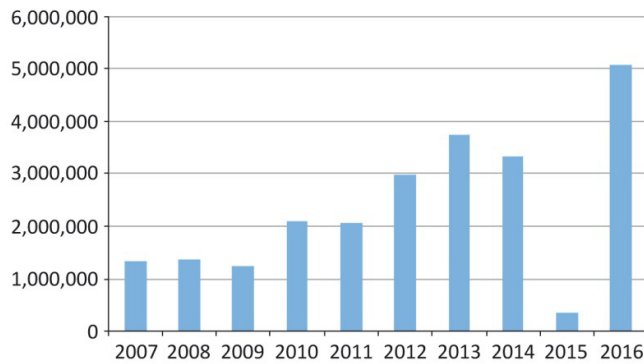
Figure A6 Cross-region power transmissions by grid regions, excluding Central and East China Grids, 10 thousand kwh



Source: Wind Info.

Data shows total cross-region power transmission increased greatly from 2015 to 2016 (Figure A7). According to the Xinhua News, in 2016, the Beijing Power Trading Centre facilitated a cross-region power transfer of 779.4 billion kwh, in which renewable energy power trading was 371.6 billion kwh, including 129.5 billion kwh hydro power, 37.4 wind and solar power.³⁴ Such an achievement can be viewed as benefiting both from policy enforcement and better facilitation.

³⁴ See http://news.xinhuanet.com/energy/2017-02/27/c_1120534010.htm

Figure A7 Change of cross-region power transmission, 10 thousand kwh

Source: Wind Info.

Enforcement on full acquisition of renewable energy power. Full acquisition of renewable energy power was written as a clause in the Renewable Energy Law launched in 2006. However, the full acquisition policy has never been implemented effectively, until 2015 when the new round power sector reform package was released and when environmental issues and high curtailment of renewable energy power, the full acquisition of renewable energy power policy was re-focused. In March 2016, a document by NDRC and NEA titled ‘Administration Measure for Full and Guaranteed Acquisition of Renewable Energy Power’ made it clear that renewable energy grid-connecting generation is divided into two parts, guaranteed (or secured) acquisition and market trading volume. The guaranteed volume is to be realized through priority generation plans, entering into priority generation contracts and fully acquired according to grid feed-in tariff; while the market trading volume is to be realized through a bidding process. In May 2016, a ‘Notice on Administration of Carrying out Wind and Solar Power Full and Guaranteed Acquisition Work’³⁵ laid out guaranteed minimum acquisition hours of wind and solar power in high curtailment regions varying from 1300 hours to 1500 hours for solar power and 1800 hours to 2000 hours per year for wind power. All other regions have to enforce full acquisition of renewable energy power. Provinces that do not meet with the minimum guaranteed acquisition requirement cannot start new wind and solar power projects (including projects that have already been included in plans or been approved). Grid companies are required to enter priority grid feed-in contracts with qualified renewable energy power generation firms.

Hence, policies regarding full acquisition of renewable energy power moved from principles to more applicable directions. Some positive implications include: (1) at the firm level, reasonable income from power dispatching for renewable energy firms warrants their sustainable operation; (2) minimum acquisition hours set out for high renewable energy power curtailment regions will push for resolving currently over stocked capacity; and (3) to some extent, to curb overinvestment in regions that already have grid feed-in difficulties.

Establishment of a priority generation scheme ensures priority grid connection. As NDRC requested local government authorities to submit 2017 priority generation and utilization plans, and the Beijing and Guangzhou Power Trading Centres to submit cross-region transmission pre-schedules, the full acquisition of planned renewable energy power and renewable power trading

³⁵ See NDRC, 2016, http://www.sdpc.gov.cn/zcfb/zcfbtz/201605/t20160531_806101.html

contracts will have been prioritized with protective scheduling in grid connection. This was stated by NDRC as one of the major tasks in the power sector reform in 2017.

As far as the renewable energy power sector is concerned, such a priority generation scheme not only provides protection to the renewable energy power generation and grid connection, but also is a move towards breaking local barriers under the old generation planning scheme.

A more recent development in the construction of a market trading mechanism is the issuance of the 'Basic Rules for Medium and Long Term Power Trading (Provisional)',³⁶ and the 'Notice on Issuance of Green Power Certificate and Voluntarily Subscription and Trade (Tentative)'.³⁷ The former works as a handbook for power trading and the latter was an official recognition of wind and solar power generation. The green certificate was aiming for promoting renewable energy efficient utilization, as well as, to reducing government direct subsidies to some extent. Green certificate voluntary subscription will start in mid 2017, and from 2018 green power quota assessment and mandate certificate trading begins.

A1.4 Outlook for the situation of renewable energy power curtailment

From work plans of the NDRC and NEA in 2017, plans for the 13th Five-Year Plan period, and the progress of grid capacity expansion, the situation of renewable energy curtailment will be improved, if other factors are unchanged.

Restrictions on the new power capacity investment in high curtail regions. In February 2017, NEA released the 'Notice on 2017 Wind Power Investment Monitoring and Early Warning Result', clearly stating that according to its zoning system, Inner Mongolia, Heilongjiang, Jilin, Gansu and Xinjiang fall into a red warning zone. These provinces/regions are prohibited to ratify any new wind power construction projects, grid companies are not allowed to accept any new applications for wind power grid connection, and local branches of NEA are not allowed to issue any new power generation permits to new wind power units in the above six regions. Transmission lines currently in operation or under construction are mainly to be used for resolving stock of installed generation capacity in these regions. It stresses that provinces and regions with mandated minimum acquisition hours have to work out detailed implementation plans and submit them to NEA by end of April, and take action accordingly.³⁸

Twelve grid lines proposed under the Action Plan for the Control of Air Pollution to be fully completed by end of 2017 according to the schedule. In September 2013, the State Council issued an Action Plan for the Control of Air Pollution, in response to this plan, NEA initiated a 12-grids construction plan to increase the delivery capacity of renewable energy power from northeast and northwest to load regions.³⁹ Construction on these 12 grids started between 2014 and 2015, some of the lines are already in operation. By end of this year, all 12 grids are to be completed with total capacity of 71 million kw. Technically, increased grid capacity will ease the high curtailment pressure to some extent.

³⁶ See NDRC and NEA, http://www.gov.cn/xinwen/2017-01/12/content_5159156.htm

³⁷ See NDRC, MOF and NEA, 2017, http://www.nea.gov.cn/2017-02/06/c_136035626.htm

³⁸ See <http://sdb.nea.gov.cn/new/2017-2/2017222113437.htm>

³⁹ See <http://news.bjx.com.cn/html/20140611/517544.shtml>

Other investment initiatives. There are proposals for the increase of constructions in pumped-storage power station and gas power station for peak shaving, and modification of current coal-fired units to increase their flexibility to undertake peak shaving for renewable units, etc. which will also help in the delivery of renewable power to other regions.

Geographical restructuring of non-hydro renewable energy power distribution. In the 13th Five-Year Plan for Renewable Energy Development, and in NEA's 2017 Energy Working Guidance, it is clear that the direction of renewable energy development will follow the principle of local production to serve for local consumption, to make a shift from overly concentrated geographical distribution of wind and solar power generation bases to allow for a relatively geographically diversified development.⁴⁰ Data from the China Electricity Council shows that in 2016, investment in wind power generation capacity decreased by 25.3% which is mainly from the drop in the western and northeastern regions, while eastern and central regions investment grew by 35.1% and 13.1%, respectively. More than 50% of the increased installed capacity was from the eastern and central regions.⁴¹

Early this year, at different occasions both the Director of the NEA and Director from the State Grid Company indicated that by 2020, the renewable energy power curtail rate will drop to within 5%.⁴²

Although the above mentioned government policies, policy implementation measures and the investment directions all indicate positive result in resolving the current high curtailment of renewable energy power, there are reasons to doubt how well the problem will be solved and to what extent. Efforts have to be made to deal with regional barriers in the renewable energy power cross-region delivery, to push for more renewable energy power consumption against the background of total power consumption shrink, and to effectively enforce the full acquisition policy.

⁴⁰ See http://www.zfxgk.nea.gov.cn/auto82/201702/t20170217_2602.htm

⁴¹ CEC, <http://www.cec.org.cn/guihuayutongji/tongjixinxi/niandushuju/2017-01-20/164007.html>

⁴² See <http://shupeidian.bjx.com.cn/news/20170308/812659.shtml> and <http://finance.sina.com.cn/roll/2017-01-26/doc-ifyzyxmt1257476.shtml>