China's "new normal": structural change, better growth, and peak emissions

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Policy brief
June 2015

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Acknowledgements

The authors are very grateful to Ehtisham Ahmad, Ross Garnaut, Karl Hallding, and Frank Jotzo for their guidance on and review of the paper. Thanks also to Rodney Boyd, Ben Caldecott, Shenghao Feng, Ajay Gambhir, Sam Geall, Himanshu Gupta, Guoyi Han, He Jiankun, Neil Hirst, Lauri Myllyvirta, Felix Preston, Qi Ye, Morten Rossé, Teng Fei, Shane Tomlinson, Wang Jianliang, Renfeng Zhao, and members of the Grantham Research Institute Policy Group for helpful discussions on various aspects of the paper. Any errors or omissions are our own.

This policy brief is intended to inform decision-makers in the public, private and third sectors. It is a longer and modified version of our paper produced for the 2015 China Development Forum, which was published in the *Journal of the China Development Forum* in March 2015 and simultaneously published by the Grantham Research Institute. The paper has been modified to reflect discussions during the Forum, and subsequent analysis. The views expressed in this paper represent those of the authors and do not necessarily represent those of the host institutions or funders.

Executive summary

China has grown rapidly — often at double-digit rates — for more than three decades by following a strategy of high investment, strong export orientation and energy-intensive manufacturing. While this growth lifted hundreds of millions out of poverty, it also heightened problems of inequality — personal, regional and urban-rural — and intensified pollution, congestion and greenhouse gas (GHG) emissions.

Recognising these difficulties, as well as the maturation of China's economy in terms of skills, productivity and rising wages, and slower growth in some of China's traditional export markets, the economic strategy has changed. China has now entered a new phase of economic development — a "new normal" — focused on better quality growth. From structural changes in the economy to explicit policies on efficiency, air pollution and clean energy, China's new development model is continuing to promote economic growth while driving down its GHG emissions.

This new strategy is now playing out in China's economy. For example, coal consumption fell in 2014, and fell further in the first quarter of 2015. Analysing trends in the key emitting sectors, we conclude that China's GHG emissions are unlikely to peak as late as 2030 — the upper limit set by President Xi Jinping in November 2014 — and are much more likely to peak by 2025. They could peak even earlier than that. With a comprehensive approach to reform, they could also fall rapidly post-peak. China's transformation has profound implications for the global economy, and greatly increases the prospects for keeping global GHG emissions within relatively safe limits.

China is moving decisively to a "new normal" — a development model based on the notion of better quality growth.

China's new development model — its "new normal" — embodies a focus on structural changes that can achieve still-strong but lower economic growth (around 7% p.a. over the next five years) of a much better quality in terms of its social distribution and impact on the natural environment. The new model places a strong emphasis on: shifting the balance of growth away from heavy-industrial investment and toward domestic consumption, particularly of *services; innovation*, as a means of raising productivity and climbing up the global value chain; reducing inequalities, especially urban–rural and regional *inequalities*; and environmental *sustainability*, emphasising reductions in air pollution and other forms of local environmental damage, as well as in GHG emissions.

Under China's new development model, its GHG emissions are likely to peak by 2025, and could well peak earlier than that.

Whereas coal consumption in China grew at around 9–10% per year in the first decade of this century, it fell in 2014 by nearly 3% according to recently released preliminary Chinese statistics, and fell even further in the first quarter of 2015. In our analysis of structural and cyclical trends in the electricity and industrial sectors, we conclude that China's coal use has reached a structural maximum and is likely to plateau over the next five years. Though there are some structural risks of coal use increasing over this period, there are possibilities, in our view more likely, that it will continue to decline. Use of natural gas in these sectors will increase rapidly over the next 5–10 years, from a low base.

In the transport, sector, China's oil consumption and carbon dioxide emissions are likely to continue growing over at least the next decade, from a relatively low base today, but existing and planned policy measures are likely to result in more moderate growth than commonly projected in many studies conducted over the past decade, with strong potential for future mitigation.

In light of Chinese economic and policy trends affecting the structure of the economy and the consumption of fossil fuels — particularly coal — across power generation, industry and transport, we conclude that the peak in China's carbon dioxide emissions from energy, and in overall GHG emissions, is unlikely to occur as late as 2030, and more likely to occur by 2025. It could well occur even earlier than that.

This suggests that China's international commitment to peak carbon dioxide emissions "around 2030" should be seen as a conservative "upper limit" from a government that prefers to under-promise and over-deliver. It is important that governments, businesses and citizens everywhere understand this fundamental change in China, reflect on their own ambitions on climate change, and adjust upwards expectations about the global market potential for low-carbon and environmental goods and services.

Were China's emissions indeed to peak around 2020–2025, it would be reasonable to expect a peak emissions level for China of around 12.5–14 billion tonnes of carbon dioxide equivalent. This could hold open the possibility that global GHG emissions could be brought onto a pathway consistent with the international goal of limiting global warming to no more than 2°C. Whether the world can get onto that pathway in the decade or more after 2020 depends in significant part on China's ability to reduce its emissions at a rapid rate, post-peak (as opposed to emissions plateauing for a long time), on the actions of other countries in the next two decades, and on global actions over the subsequent decades.

To reduce its emissions at a rapid rate, post-peak, China will need to deepen its planned reforms in cities and in the energy system, supported by a concerted approach to clean innovation, green finance and fiscal reforms.

Key structures and policy measures China could put in place to reduce its emissions at a rapid rate include:

- Planning cities along the lines of the compact, high-density, public transport-linked models.
- Transforming the energy system through: enhanced policies and measures to improve energy efficiency; accelerated expansion of non-coal energy generation sources; avoidance of new (unabated) coal initiatives such as coal-to-gas facilities and western coal bases; a strategy for managing the phase-out of coal-fired power stations (unless equipped with carbon capture and storage); the electrification of passenger transport (and some other processes); and continued efforts to manage an increasingly complex energy grid.
- Enhancing institutional and policy support for clean innovation — particularly an increasing focus on the demonstration and deployment at scale of key clean technologies with high potential for emissions reductions and cost reductions.
- Implementing measures to shift China's financial sector towards a green financial system that can finance low-pollution, low-carbon, resource-efficient infrastructure at a low cost of capital.

- Introducing a tax on coal that better reflects (among other things) the costs of local environmental and global climate impacts, as part of a wider package of fiscal, energy pricing, and governance reforms. The revenues from such a coal tax would be considerable and could partly be applied toward clean energy innovation (with high potential for fuelling economic growth), and partly toward removing less efficient taxes, assisting with structural adjustment, and protecting those on low incomes.

Achieving strong economic growth of a high quality — with low pollution, congestion and waste; attractive and liveable cities, and a clean and secure energy system — requires that China's "new normal" entail a concerted commitment to a continuing and dynamic process of structural transformation and policy reform. In undertaking this process, China can set an example for the world on how to achieve these crucial objectives together.

Introduction

China's economy is currently undergoing a major structural transformation towards a new development model focused on achieving better quality growth that is more economically and environmentally sustainable, and achieves better social outcomes for the Chinese people. This paper traces the origins and explains the content of this new growth model, and considers its likely implications for the trajectory of China's greenhouse gas (GHG) emissions. In so doing, we hope to contribute to an important policy debate concerning the future direction of China's economy and its role in responding to global climate change.

The paper is divided into three Parts, each with two or three chapters. Part I explains the content of China's new development model and traces its origins as a response to the unsustainable and undesirable implications of China's old model of growth. This provides the necessary context for analysing trends in China's economic structure, policy reform efforts, and GHG emissions.

Part II is more forward-looking, and is concerned with analysing medium-term trends in China's GHG emissions with a view to ascertaining when emissions are likely to peak. Chapter 3 (and Appendix I) examines the findings of a groundbreaking study undertaken by the Global Commission on the Economy and Climate, *China and the New Climate Economy* — which modelled the implications for carbon dioxide emissions, air pollution, energy security, and economic costs of a scenario in which China's emissions peak in 2030. This modelling work served as a key input into the development of China's important commitment, announced by President Xi in November 2014, to peak China's carbon dioxide emissions around 2030. But economic and policy change are occurring so rapidly in China that statistical and policy trends since the Commission's modelling was undertaken, and since the announcement of China's 2030 commitment, suggest the potential for a peak in China's carbon dioxide emissions considerably earlier than 2030. Accordingly, Chapter 4, which constitutes the core contribution of this paper, undertakes a bottom-up analysis of trends in the highest emitting sectors (electricity, industry, and transport) to consider the prospects for an earlier peaking date, and relatively low peaking level, for China's emissions.

Part III looks still further ahead, and is more prescriptive in its approach. It sets out the key areas of policy and structural reform where China will likely need to focus in order to reduce its emissions strongly, post-peak.

Our core argument is that, under the conditions of China's new development model, China's GHG emissions are likely to peak by 2025, and could well peak even earlier than that. With the kinds of policies we outline in Part III, China's emissions could fall strongly after their peak. These outcomes are not only eminently achievable, but if the process of structural change is managed well, would likely be strongly beneficial to China for reasons quite aside from the long-term reductions in climate risk.

In the concluding section of the paper, we briefly highlight some implications of our analysis for China's role in *global* climate policy, including in relation to the international negotiations occurring at the United Nations Climate Change Conference in Paris at the end of 2015. This topic is given more thorough treatment in our accompanying Policy Paper, *The Road to Paris and Beyond: International Climate Cooperation and the Role of China* (Boyd, Green and Stern, 2015).

Part I — Structural change, better growth

Since its period of reform and opening-up took hold in the last two decades of the 20th century, China has been at the forefront of many global economic trends — the shifting locus of economic activity from West to East, rapid economic growth, urbanisation, and demographic change — all of which have lifted hundreds of millions of Chinese out of poverty. But underlying these long-term trends, China's development over this period has involved different phases; periods of continuity punctuated by major structural shifts. One such major shift came at the turn of the century, as China rapidly developed its energy-intensive, heavy-industrial sectors. Below we briefly outline the key features of that development phase, which provides the necessary context to understand the abrupt structural shift that China is undertaking now to a model of "better growth".

1. Precursors to China's "new normal"

China has been growing very rapidly, often at double-digit rates for more than three decades. Its strategy has been centred on high investment, strong export orientation, and a focus on manufacturing industry and construction. Over the period 2000–2011 in particular, China's growth strategy was characterised by (Garnaut et. al., 2014; CCICED, 2014):

- double-digit GDP growth (on average)
- a very high investment share of expenditure, with exceptionally low proportions of expenditure on domestic consumption and on services
- very high levels of investment in heavy industrial sectors such as steel and cement, which require large volumes of energy, and with the latter supplied predominantly through coal-fired power generation
- a high profit share of income
- strong dependence on exports to external markets.

China's leaders and the Chinese people have increasingly come to recognise that this model of growth is now both unsustainable and undesirable — for conventional economic, social, local environmental and global climatic reasons (Garnaut et al., 2013). As President Xi remarked in late 2013, China's current growth model is "unbalanced, uncoordinated and unsustainable" (quoted in Anon., 2013).[1]

First, China's growth model is environmentally unsustainable. In particular, China's reliance on coal-fired power and heavy industries, and its growing vehicle use in urban areas, have led to rising air pollution and haze, to which growing numbers of urban residents are exposed as China urbanises (CCICED, 2014; World Bank and DRC, 2014). It is also exacting a high price in its impact on public health. Particulate matter (PM2.5) pollution in China has been linked to 1.23 million premature deaths in 2010 (median estimate) — or, in monetary terms, damages equivalent to 9.7–13.2% of China's GDP (GCEC, 2014a; Hamilton, 2015). Other environmental

1 The remarks were made in President Xi's address to the CPC Central Committee at its Third Plenum in November 2013.

impacts are mounting, too, including water pollution and water scarcity, soil pollution, solid waste, and other forms of ecological degradation (CCICED, 2014; World Bank and DRC, 2014). These, in turn, have contributed to some of the economic and social challenges discussed below.

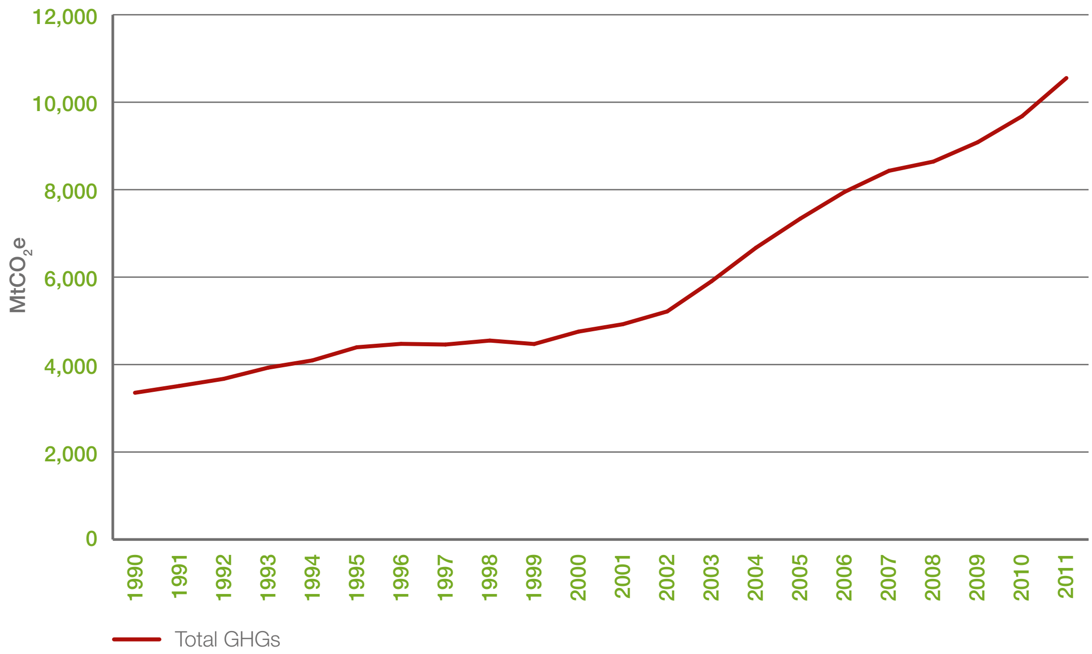
In a conventional economic sense, the old model of growth is unsustainable for at least three reasons. First, it has resulted in serious over-investment and diminishing returns on capital, as well as widespread over-capacity in China's energy intensive sectors, undermining their competitiveness (CCICED, 2014; World Bank and DRC, 2014).[2] Second, China's labour force is changing. The proportion of China's population of working age (i.e. between 16 and 60 years old) has fallen for the last three years consecutively and is expected to continue to decline, reflecting the long-term implications of China's One Child Policy (Fan, 2015). Meanwhile, wages are rising, meaning future competitiveness will depend on a structural shift toward higher value-added industries that pay higher wages, particularly in the services sector (Drysdale, 2015; Garnaut et al., 2013). Third, natural resource constraints, environmental deterioration and rising dependence on imported energy are all increasingly undermining China's economic performance, imposing rising direct and indirect economic costs (CCICED, 2014; World Bank and DRC, 2014).

The old model of growth, while lifting hundreds of millions of Chinese out of poverty, has also produced various undesirable social impacts that are adding to pressures for reform. Most prominently, it led to growing inequalities of different kinds. Rapid urbanisation and urban economic growth, combined with China's restrictive residential registration (*hukou*) system, which inhibits internal labour flows, has led to rising urban-rural inequality and social divisions between registered and unregistered urban residents (World Bank and DRC, 2014). There has also been growing inequality between regions, as the growth was disproportionately concentrated in the eastern coastal cities, though with an increasing shift toward central regions in recent years (Anon., 2015a). In addition, the low-wage/high-profit structure of the old growth model, combined with the relatively low expenditure on social services, contributed to rising interpersonal inequality (Garnaut et al., 2013). Moreover, the health impacts of pollution and environmental degradation have created immense and escalating social pressures for change.

Finally, this phase of China's development also caused high growth in China's greenhouse gas (GHG) emissions (see Figure 1.1, below), the unsustainability of which is discussed in Chapter 3.

2 Commenting on the links between overinvestment, overcapacity and China's industrial competitiveness, the CCICED (2014) points out that: "By the end of 2012, capacity utilisation in the iron and steel, cement, electrolytic aluminium, flat glass and shipbuilding sectors ranged from 72% to 75% — significantly lower than the international average. With a large amount of idle production capacity, many enterprises cannot generate reasonable returns on investments and are increasingly faced with losses and operational difficulties."

Figure 1. China's GHG emissions, 1990-2011



Source: data from WRI (2014).

Note the WRI dataset is at the lower end of the range of data for China's emissions — compare the data from IEA (2015a) and see our discussion of upward revisions in China's coal consumption statistics in the five-year period to 2013 in footnote 66, below.

2. China's "new normal": structural change, better growth

As a result of both the successes of the old growth model and the mounting pressures it has brought, deep and wide-raging changes in structure and policy are now occurring — changes "so comprehensive and profound that they add up to a new model of Chinese economic growth" (Garnaut et al., 2013, 1). Over the last two years, that new model has been articulated with increasing force and clarity at the highest levels of China's government (CCCPC, 2013; State Council, 2013; Zhang, 2014; Anon., 2015b). In shorthand form, China's "new normal" is understood by China's leadership and policy elite as having *better quality growth* at its core, with a particular emphasis on four sub-themes: *services, innovation, reduced inequality* and *environmental sustainability.*[3]

The role of these four sub-themes, and their relationship both to better quality growth and lower GHG emissions, can be understood by decomposing growth into the following elements: growth rate; composition; energy intensity; and carbon intensity (the last two of these and their relationship to growth are discussed further, in a more technical and formal way, in Box 2 in Chapter 6).

- **Growth rate:** The first transformation in China's growth model is evident in the slowing headline rate of GDP growth, from an average of 10.5% over the period 2000–2010, to 7–8% over 2012–2014 (World Bank, 2015a; IMF, 2015).[4] In its latest projections, the IMF (2015,) projects China's growth to slow to 6.8% in 2015 and 6.3% in 2016. A reasonable expectation for 2020–2030 would be average growth of 4–6%, depending on China's success in implementing structural reforms.[5] A gradually slowing rate of Chinese growth toward developed country norms is a consequence of economic maturation, and reflects China's shift away from a model focused on the quantity of growth — which as we have seen is unsustainable — to one focused on its quality.

- **Composition of growth:** China's slowing growth rate is linked to the changing structure of China's economy. A gradual rebalancing of growth toward lower investment and higher consumption (both private and public) is widely regarded as desirable for economic, social and environmental reasons (CCICED 2014; World Bank and DRC, 2013). Greater and more inclusive government expenditures on social security and public services, particularly healthcare and education, will help to reduce inequalities (CCICED, 2014). Moreover, a lower overall investment share of GDP and a shift in capital allocation away from heavy industrial sectors (especially in low value-added products such as steel and cement) and toward service sectors and higher value-added manufacturing, as has been gradually occurring, will raise productivity as traditional industries decline (CCICED, 2014). Becoming a more innovative producer is particularly important to China's aspirations to move up the global value chain. China is beginning to play more of a leading role in various innovative sectors, including clean energy, drawing on its growing base of skills and research and development capabilities.

3 This summary definition of the "new normal" concept is based on Stern's discussions with Chinese leaders and policymakers at the China Development Forum in March 2015, for which an earlier version of this paper was prepared. These four sub-themes are also apparent from key documents produced under China's new leadership over the last two years, such as those cited in this paragraph.

4 According to World Bank data (2015a,), China's GDP growth (at market prices in 2010 $) fell from 9.3% in 2011 to 7.7% in 2012, 7.7% in 2013, and 7.4% (World Bank estimate) in 2014. The IMF (2015) concludes that China's real GDP growth in 2014 was indeed 7.4%.

5 See, e.g., the growth scenarios projected in the New Climate Economy China Study (GCEC, 2014b), reproduced in Appendix I, Table A1.1, below.

- **Energy intensity of growth:** Reducing the energy intensity of economic growth is fundamental to China's new development model. Greater energy efficiency in China contributes to economic growth by enhancing productivity (Ward et al., 2012) and by growing the (innovative and job-intensive) energy efficiency goods and services sector. It also reduces air pollution and GHG emissions by reducing overall energy demand (Green and Stern, 2014).

- **Carbon intensity of energy and low-pollution energy supply:** Finally, substituting away from coal as an energy source toward sources that produce low or zero emissions of GHGs and local air pollutants is essential for the environmental sustainability of China's growth model, while also improving energy security and contributing to the development of innovative growth industries.

These structural changes are emerging partly as a result of changes in the domestic and international economy that have emerged as a consequence of the old model of growth, and partly as a result of explicit government policy (Garnaut et al., 2013, 1). To date, government policy has played a particularly important role in the latter two components of structural change, concerning energy efficiency and the energy supply.

Reducing the energy intensity of growth has been a major priority of China since at least the 11th Five-Year Plan (2006–2010), with the initial focus primarily on improving industrial energy efficiency through the replacement of small, inefficient plants with larger and more efficient alternatives. These and other initiatives in various sectors[6] have contributed to a steady decline in the energy intensity of China's economy over the last decade, following a spike in the early 2000s (Green and Stern, 2014).

Additionally, Chinese policy has had a major effect on the energy mix, particularly in the power sector. First, China has improved the efficiency of its coal-fired power generation fleet through closing down many of its least efficient and highest polluting plants, replacing them with larger and more efficient ones. Second, over the last 18 months China has imposed tight new restrictions on coal consumption, particularly in the key economic regions, through its Airborne Pollution Prevention and Control Plan (State Council 2013).[7] Third, China has provided strong financing and policy support for the development, manufacturing and deployment of low- and zero-emissions energy sources.[8] China's investment (public and private) in renewable energy has been particularly strong, growing from US$3 billion in 2004 to a high of US$83.3 billion — nearly one-third of the global total — in 2014 (Frankfurt School–UNEP Centre and BNEF, 2015).[9] In addition, China deployed more than 70 gigawatts (GW) of non-coal electric generation capacity in 2014, including more than 53GW of hydro, wind and solar capacity (see Appendix II) — by far the largest in the world.

The above summary of the structural transformation in China's economy associated with the new development model provides the context for our analysis of trends in China's GHG emissions, which is the subject of the next part of this paper. It can readily be seen that each component of China's "new normal" — from the lower growth rate down to the changing composition of energy supply — has the effect of reducing China's GHG emissions, whether

6 For a list and description of China's energy efficiency policy measures, search for "China" in the IEA's Energy Efficiency Policies and Measures database: http://www.iea.org/policiesandmeasures/energyefficiency/.

7 The Plan imposes various types of restrictions on coal and heavy industry. Nationally, it sets mid- and long-term caps on coal consumption and aims to decrease the share of coal in total energy consumption to less than 65% by 2017. In the key economic regions that are heavily affected by air pollution — Beijing-Tianjin-Hebei, Yangtze River Delta and Pearl River Delta — the Plan prohibits the building of new coal-fired power plants and aims to achieve absolute reductions in coal consumption by 2017. It also aims to remove parts of heavy industry from these regions. See Slater (2014).

8 China's clean technology development is also export-oriented. For discussion, see Boyd, Green and Stern (2015) and Garnaut (2014). Our present focus, however, is with trends in China's domestic energy supply.

9 These figures exclude investments in large hydroelectric projects of more than 50MW.

intended or incidental. The cumulative mitigation potential associated with the full implementation of this new model could therefore be very large indeed.

Before examining China's emissions, we note that China's reform agenda is ambitious and entails risks: structural change always involves transitional costs and dislocation, which need to be managed carefully; and, as in all polities, there are those with vested interests in the status quo who will resist change. It is possible that short-term challenges will induce political pressures to slow reform and revert to the old model of growth. But the risks to China of stalling reform far outweigh those of pressing ahead with reform (see also Garnaut, 2014,; Anon., 2015a), a reality that China's leaders fully appreciate. Moreover, as we discuss further in Chapter 7, structural reform towards a low-carbon model can be carried out in a fair and orderly way that makes it easier to manage the associated dislocation.

Part II — Peak emissions

This part of the paper focuses on the future, particularly the future direction of China's greenhouse gas (GHG) emissions in the context of the new development model.

When looking forward, it is necessary to consider, in addition to the structural changes already occurring and the policies already implemented, China's official targets regarding future GHG emissions and clean energy deployment, which include:

- Reduce the emissions intensity of economic growth 40–45% below 2005 levels by 2020 (enshrined internationally in the Copenhagen Accord of 2009 and Cancun Agreements of 2010).
- Peak its carbon dioxide emissions around 2030, with the intention of peaking earlier (commitment made in November 2014 as part of a joint Sino-US announcement on climate change by Presidents Xi and Obama: Xinhua, 2014a; Whitehouse, 2014).
- Raise the non-fossil fuel share of its primary energy to around 20% by 2030 (Xinhua, 2014a) and to around 15% by 2020 (State Council, 2014), up from around 10% in 2013 (the 2030 target was also part of the Xi–Obama announcement).

These are developments of global importance. The structural changes associated with China's new development model, and its specific targets on climate change, at the very least, imply the avoidance of the extremely high Chinese emissions scenario by 2030 that many had feared during the first decade of this century.[10]

However, the precise level and peaking year of China's emissions, and their trajectory post-peak (plateau or falling strongly), remain uncertain. Within the parameters of China's new development model and its official climate targets to date, there are better and worse possibilities. The remaining chapters of the paper are dedicated to examining these possibilities.

There are various methods that could be employed for this purpose. Many studies use economic models of various kinds and sophistication. Some project emissions outcomes based on underlying assumptions about trends in sets of headline parameters, such as GDP–energy intensity–carbon intensity (e.g. He, 2014; Teng and Jotzo, 2014), or relationships between per capita income growth, per capita emissions growth, and population growth (e.g. Wu 2015). Others use general equilibrium models with detailed representation of the energy sector (e.g. Zhang et al., 2014).

Chapter 3 summarises and analyses the findings of a 2014 study by the Global Commission on the Economy and Climate (GCEC),[11] which examined a scenario in which China's emissions peak in 2030, and the associated co-benefits and costs, using macroeconomic, energy sector, and air pollution models. We consider the study's findings on China's GHG emissions in relation to the wider, global emissions reduction task. This provides a useful context for our analysis of likely emissions trends in China over the next 5–10 years, which is the subject of Chapter 4. In contrast to the top-down modelling studies, our analysis takes a "bottom-up" approach, looking at fossil fuel use and emissions trends, and their drivers, in three key emitting sectors, from which we draw conclusions about likely and plausible emissions peaks.

10 See, e.g., Shealy and Dorian (2010) regarding coal consumption. Some scholars and expert agencies continued to forecast continued very high Chinese coal consumption (>6GT/year by 2030) as recently as 2013 (see, e.g., EIA 2013a, reference case).

11 Stern is the Co-Chair of the Commission and Chair of its Economics Advisory Panel.

3. The New Climate Economy China Study: findings and implications

Some possibilities for China's emissions trajectory and peak, and associated policy and planning options, have been investigated by the New Climate Economy (NCE) project of the Global Commission on the Economy and Climate (GCEC). The headline findings of the Commission's groundbreaking study, *China and the New Climate Economy* (GCEC, 2014b) (the NCE China Study) are summarised in Table 1 and explained in more detail in Appendix I.[12]

Table 1. Comparison of key results from the "continued" and "accelerated" emissions reduction scenarios in the NCE China Study's energy modelling

		Continued Emissions Reduction Scenario		Accelerated Emissions Reduction Scenario	
Variable	**2010 (actual)**	**2020**	**2030**	**2020**	**2030**
Total Energy Consumption (billion tonnes of coal equivalent)	3.25	4.92	6.25	4.75	5.9
Energy Intensity of GDP (2010 = 100)	100	73.4	54.6	70.6	51.6
CO_2 emissions from energy (GT)	7.25	10.4	12.7	9.68	10.6
CO_2 intensity (energy) of GDP (2010 = 100)	100	69.6	51.1	64.8	41.5
Proportion of non-fossil energy (%)	8.6	14.5	20	15	23
Total GHG emissions (GT CO_2e)*	***9.4***	***13.5***	***16.5***	***12.6***	***13.8***

Source: GCEC (2014b, p 82, Table 4.4; does not include total GHG emissions results)

Note: All results assume economic growth averaging 7.31% between 2010–2020, and 4.77% between 2020–2030, based on the NCE China Study's "Middle" economic growth scenario.

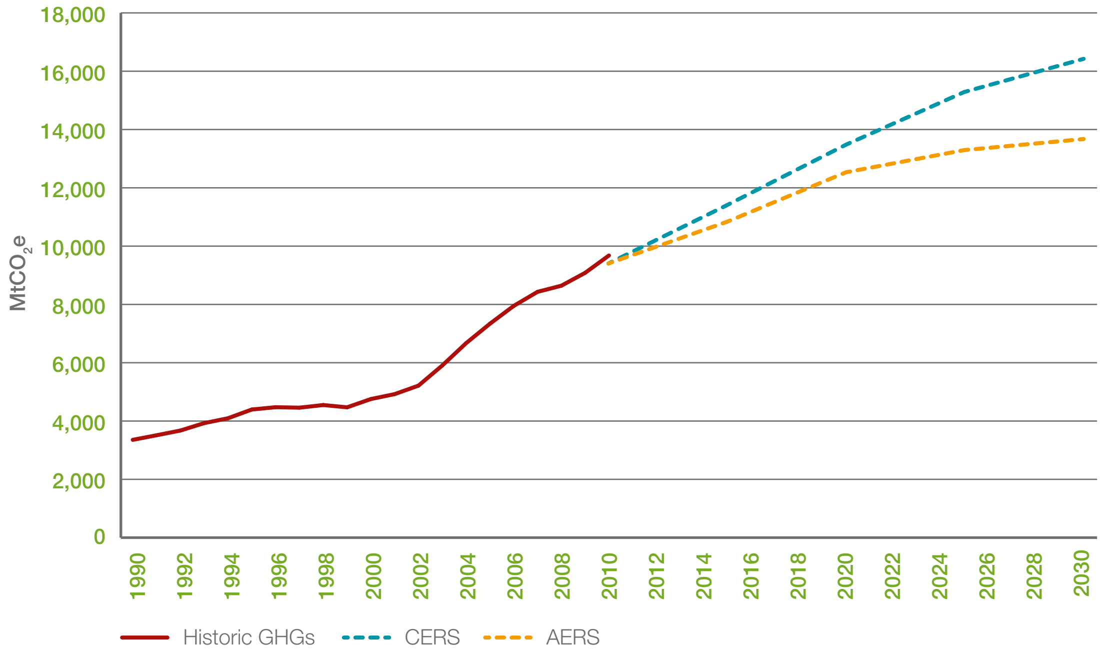
** Total GHG emissions results calculated by authors assuming a constant ratio of CO_2 emissions from energy to total GHG emissions (including land use change and forestry) of 1:1.3, based on 2010 data from WRI (2014).*[13]

12 The NCE China Study was the first of its kind to examine the economic, energy security and air pollution co-benefits of significant GHG emissions constraints in China. As such, it makes an outstanding contribution to the literature and policy debate concerning the relative merits of alternative Chinese economic development pathways.

13 This method of projecting total GHG emissions may somewhat overstate future GHG emissions projections, since it is likely that non-CO_2 emissions (especially CH_4 and N_2O from the agriculture sector, and HFCs and N_2O from industry) will not grow as fast as CO_2. On the other hand, the WRI dataset is at the lower end of the range of data for China's emissions — compare the data from IEA (2015a). Moreover, the model is being updated to reflect the recent revisions to China's energy statistics in light of the five-yearly economic census done in 2014, which will likely increase the level of emissions in the projections (see footnote 66, below).

The overall GHG emissions pathways to 2030 implied by the study's projected emissions from the energy sector are displayed in Figure 2, below. The key implication of the study's "accelerated" scenario is that China's GHG emissions could peak at below 14 billion tonnes (gigatonnes, or GT) of carbon dioxide equivalent (CO_2e)[14] in 2030 (with per capita emissions at less than 10 tonnes[15]) while maintaining strong economic growth (averaging around 6% p.a. over the period 2010–2030[16]), and with significant benefits in the form of greater energy security and reduced air pollution (GCEC, 2014b). This scenario compares favourably with the study's "continued" effort scenario, under which China's carbon dioxide emissions from energy generation alone are projected to reach 12.7GT in 2030, implying total GHG emissions of around 16.5GT, or 11 tonnes per capita.[17]

Figure 2. Projected Chinese GHG emissions based on the NCE China Study's energy modelling



Source: Historic GHG data from WRI (2014); Projections from GCEC (2014b). CERS = the Study's "Continued Emissions Reduction Scenario". AERS = the Study's "Accelerated Emissions Reduction Scenario". Both CERS and AERS are adjusted by the authors from energy CO_2 emissions to total GHG emissions — see note to Table 1, above.

14 Carbon dioxide equivalent (CO_2e) is a unit that takes into account the radiative forcing of all greenhouse gases (as defined in the Kyoto Protocol), including but not limited to CO_2.

15 Assuming a Chinese population in 2030 of 1.47 billion people, consistent with the population forecast used for the study's medium GDP growth scenario (GCEC 2014b, p 52, Table 3.5), China's emissions would be 9.5tCO_2e per capita.

16 Based on the study's "medium" economic growth scenario. See Appendix I, Table A1.1, below.

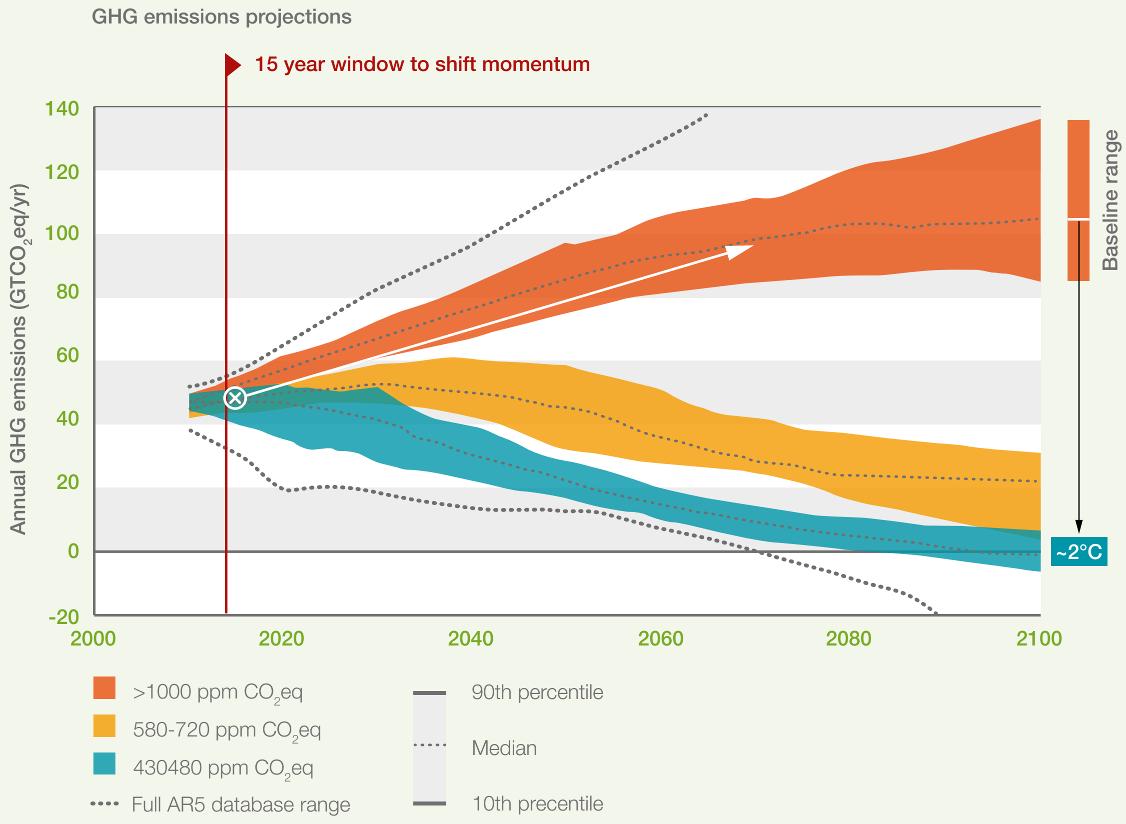
17 Assuming a Chinese population in 2030 of 1.47 billion people, consistent with the population forecast used for the study's medium GDP growth scenario (GCEC 2014b, p 52, Table 3.5).

Nonetheless, even if China's emissions were to peak in 2030 at just below 14GTCO_2e, as per the "accelerated" scenario, it would be difficult to contain global emissions within levels that would put the world on a plausible trajectory for holding global warming to below 2°C (with a "likely" chance). A reasonable 2030 benchmark for such a trajectory is 35GTCO_2e (see Box 1, below). If China's emissions were at 14GT in 2030 then China, with a predicted 20% of the world's population at that time, would be taking up around 40% of the carbon space in terms of annual flows of emissions (if China's emissions were at 16.5GT, in line with the "continued effort" scenario, it would be taking up almost half of the available carbon space).[18]

Box 1. The appropriate 2030 global emissions benchmark

To achieve a "likely" (greater than 66%) chance of holding global temperature increases to within 2°C — the internationally agreed policy objective — global emissions have to be cut from over 50GCO_2e per annum now to well below 20GT in 2050 — a factor of 2.5 between 2010 and 2050 (IPCC 2014,; Figure 3, below).[19] That means — assuming population grows from around 7 billion now, to 8 billion in 2030, to 9.5 billion in 2050 — that global emissions per capita should diminish from around 7 tonnes of CO_2e per annum to around 2 tonnes in 2050.

Figure 3. Representative emissions pathways for alternative mitigation scenarios



Source: GCEC (2014a) based on IPCC (2014, Figure SPM.4)

18 If we adopt the higher 2030 global benchmark (for a "likely" chance of 2°C) of 42GTCO_2e (the IPCC's median value — see Box 3.1, above), 14GT of Chinese emissions in 2030 would equate to one-third of the available carbon space (39% if China's 2030 emissions were at 16.5GT). If we adopt the lower 2030 global benchmark of 28GTCO_2e (the IPCC's 10th percentile value), 14GT of Chinese emissions in 2030 would equate to 50% of the available carbon space (59% if China's emissions were at 16.5GT).

Since this paper focuses primarily on economic transformations and emissions reductions in the period up to around 2030, it is important to consider the appropriate benchmark for global emissions in 2030. The median value for the level of emissions in 2030 in the IPCC's scenarios for a "likely" (greater than 66% chance) of limiting global warming to no more than 2°C is 42GTCO_2e,[20] though this embodies strong assumptions about the ability to achieve negative emissions from energy and industry in the second half of this century. Given uncertainty about the viability of negative emissions technologies, and the higher risks more generally implicit in a higher (42GT) 2030 benchmark, a 2030 benchmark toward the lower end of the IPCC's range of "likely" 2°C pathways, e.g. around 28GT,[21] would arguably be more desirable. For consistency and clarity throughout this paper, we use a value of ~35GT as our desired 2030 global emissions benchmark (the mid-point between 28 and 42GT),[22] and explain in the footnotes the extent to which the conclusions differ if 2030 benchmarks of 28GT and 42GT are used, instead.

It is ultimately the cumulative emissions that matter, hence whatever interim benchmarks for annual flows of emissions are adopted, we can always do less emissions reduction now and more later, or vice versa, within relevant (technical, economic, social etc.) limits.

Of course, the above comparisons do not take into account responsibilities for historical emissions, the differing levels of development, and different technical capacities in different countries, hence it is important to consider China's position relative to other countries. Excluding, for the moment, the emissions of China, the US and the European Union (EU) (the three largest emitters), if all other countries increased their ambition in accordance with the IEA's "450 scenario" (IEA, 2014a), their total emissions in 2030[23] would be ~23GTCO_2e.[24] To stay within the 35GT benchmark, that would "leave" a total of 12GT for China, the US and the EU combined (Boyd, Stern and Ward 2015).[25] Thus, *even if the US and EU reduced emissions to zero in 2030* (which is clearly extremely unlikely),[26] that would "leave" a maximum of 12GT for

19 Roughly 20GTCO_2e is the median value in 2050 of the IPCC's scenarios for holding average global temperature rise to within 2°C with a "likely" (greater than 66%) chance (IPCC 2014, Figure SPM.4).

20 Accordingly, 42GTCO_2e is the benchmark for emissions in 2030 used by the GCEC in its analysis (2014a; 2015).

21 The level of emissions in 2030 corresponding to the 10th percentile of the IPCC's "likely" 2°C scenarios is around 28GT (IPCC 2014, Figure SPM.4).

22 See also UNEP (2014), which analysed model projections that limit global warming to less than 2°C (50–66% chance) but that do not assume that net negative carbon dioxide emissions from energy and industry occur during the 21st century. These pathways have a median value of 36GTCO_2e in 2030, i.e. very close to the 35GT benchmark figure we use for 2030.

23 Including emissions from international bunker fuels.

24 The IEA's New 450 Scenario is a scenario in the World Energy Outlook that sets out an energy pathway consistent with the goal of limiting the global increase in temperature to 2°C by limiting the concentration of GHGs in the atmosphere to around 450 parts per million of CO_2. See http://www.iea.org/publications/scenariosandprojections/. Note that the IEA's value of aggregate emissions in 2030 under this scenario is ~38GT (compared with our 35GT); thus if the IEA had adopted a 35GT benchmark, it might have assumed an aggregate for all other (non US-EU-China) countries of closer to 21GT (assuming a proportional adjustment of 35/38).

25 If we used a benchmark of 42GT by 2030, that would leave 19GT for China-US-EU. If we used a benchmark of 28GT, that would leave only 5GT for China-US-EU.

26 On their current trajectories, based on recent policy announcements (EU target of 40% emissions reductions below 1990 levels by 2030; US target of 26–28% emissions reductions below 2005 levels by 2025), the EU is projected to be at 3.2GT in 2030, and the US at 3.9GT (Boyd, Stern and Ward 2015). For comparison, the IEA (2014a), in its "450 Scenario", allocates 13.1GT in 2030 to the US-EU-China as follows: EU 2.6GT; US3.3GT; China 7.2GT.

China.[27] It does look as if the world will be substantially above where it would need to be in 2030 for 2°C.

Since global emissions are likely to be higher in 2030 than the 35GT benchmark for 2°C, we will have a lot catching up to do. The challenge is to limit the amount of catching up that is required, and to put ourselves in a strong position to reduce emissions rapidly post-2030. In this context, a reasonable implication of the above analysis is that 12GTCO_2e would need to be seen as an upper limit for China's emissions in 2030 if the world is to get onto a 2°C pathway, and that a Chinese target of less than 10GTCO_2e (less than 7 tonnes per capita) in 2030 would be more desirable from a global climate perspective. Even achieving the latter target would imply the need for continued strong reductions in emissions after that time, which will require careful planning in the near term.

China's leaders are cognisant of this "unforgiving math of accumulated emissions",[28] however inequitable it may seem in light of historical responsibility for emissions. It is part of the reason why China's policies and investments to restrain emissions, and to implement China's new development model more generally, have accelerated considerably over the last 12 months, since the work for the NCE China Study was undertaken. Indeed, such is the pace of change in China that the "accelerated" effort scenario modelled in the NCE China Study has now been surpassed in terms of both policy developments and statistical trends.

In this context, it is appropriate to consider whether recent developments in China imply the possibility of an emissions peak significantly earlier than 2030, and at a level of emissions significantly lower than projected in the NCE China Study's modelling.

27 Within a range of 5–19GT, corresponding to a range for 2030 emissions benchmarks of 28–42GT (see footnote 25 and Box 3.1, above).

28 Quote by Todd Stern in US Department of State (2009).

4. Prospects for an early and low peak in China's greenhouse gas emissions

This chapter considers the prospects for a relatively early and low peak in China's greenhouse gas (GHG) emissions by analysing trends in the three highest-emitting sectors — electricity generation, industry and transport — and then considers trends in overall emissions from fossil fuel emissions.

4.1 Electricity sector

Falling coal use in China over the last year suggests the possibility that emissions from China's electricity sector — roughly 40% of China's total GHG emissions — have already peaked. We conclude it is likely that China's electricity emissions at least reached their structural maximum in 2013/2014 and are likely to plateau (possibly with minor cyclical variations around the current level), and could well fall slightly on average over the coming decade.[29] Below we explain and justify this conclusion.

During the first decade of this century, strong growth in electricity consumption and the predominance of coal in China's electricity mix drove China's emissions from electricity to historic highs (more than 4GTCO_2 in 2011 (WRI, 2014)).[30] During this period, electricity production experienced double digit growth (EIA, 2013b), and coal use in electricity grew at over 11% per year (Garnaut, 2014), leading many experts and institutes to forecast continued dramatic increases in China's coal consumption and, hence, electricity emissions (see, e.g., EIA, 2013a).

In 2012 and 2013, statistics on electricity consumption and coal consumption in electricity reveal a more mixed picture, with signs of both moderation and continued strong growth in both.[31] Reflecting this, a difference of opinion has emerged among experts about the extent of the shift in electricity demand and coal consumption trends. The International Energy Agency (IEA), in its latest New Policies Scenario,[32] forecasts electricity demand growth in China of 4.8% per year between 2012 and 2020 (IEA 2014a), and continued growth in coal consumption in electricity generation until at least 2040.[33] By contrast, Garnaut (2014) forecast electricity production growth of 4% p.a., and a slight *decline* (of 0.1% p.a. on average) in the absolute volume of coal use in electricity from 2013 to 2020 (he considered these to be conservatively *high* forecasts), reflecting his analysis that China's new development model is increasingly taking root, and is likely to entail more fundamental changes in the structure of Chinese demand for, and production of, electricity. Garnaut's conclusion that coal use in electricity has peaked and will fall (slightly) over the remainder of the decade represents, in his view, "a turnaround of historic dimension and global importance".

29 By structural maximum, we mean a maximum controlling for (i) cyclical variability in hydroelectricity output, and (ii) the backloading of non-coal energy expansions across five-year plans, both of which are discussed below.

30 WRI's figure (4.27GTCO_2) includes emissions from electricity and heat.

31 Compare data from the National Bureau of Statistics in 2014 (reported in Ma, 2014) with Garnaut (2014, 9, Table 1) and the most recent NBS statistics (NBS, 2015a). And see footnote 66 and Myllyvirta (2015a) for a discussion of under-reporting of the pre–2014 coal data.

32 The IEA's New Policies Scenario is a scenario in the World Energy Outlook that takes account of broad policy commitments and plans that have been announced by countries, including national pledges to reduce GHG emissions and plans to phase out fossil-energy subsidies, even if the measures to implement these commitments have yet to be identified or announced. This broadly serves as the IEA baseline scenario. See http://www.iea.org/publications/scenariosandprojections/.

33 The New Policies Scenario will be updated in the 2015 World Energy Outlook, which had not been published at the time of writing.

Recently released preliminary Chinese statistics for 2014 and the first quarter (Q1) of 2015 lend strong weight to Garnaut's assessment, suggesting, if anything, that the turnaround in coal consumption in electricity is even *more* profound than he predicted:[34]

- **Electricity production and demand:** According to the China Electricity Council (CEC), electricity generation output grew 3.6% in 2014 (CEC, 2015b) — even lower than Garnaut's forecast[35] — and electricity demand grew only 3.8% (CEC, 2015b; NEA, 2015a), a full percentage point lower than the IEA's forecast. In Q1 2015, electricity generation output actually *fell* slightly in absolute terms (by 0.1%), compared with the same period in 2014 (NBS 2015b) — a dramatic turnaround compared with even the most ambitiously low forecasts of recent years.

- **Coal-fired power generation:** Within the power generation sector, coal-fired power generation appears to have fallen in 2014 by around 1.4%, reflecting the slower demand growth in electricity and the expansion of non-coal sources in the electricity generation mix.[36] In Q1, this trend accelerated: thermal power generation fell 3.7% (NBS, 2015b), and since non-coal thermal power output (particularly gas) would have expanded in this period, we can infer that coal-fired power generation fell even more than this, likely by more than 4% year-on year.[37]

- **Coal use in power generation:** "Apparent coal use" in electricity fell 3% in the first 11 months of 2014 according to data from the China Coal Industry Association (Anon., 2015c), reflecting (in addition to the above-mentioned factors) the increased efficiency of coal-fired power generation. In Q1 2015, coal consumption per kWh of power generated also fell year-on-year by more than 2%,[38] meaning coal use in the power sector could have fallen by more than 6% year-on-year.[39]

In our view, these 2014 and Q1 2015 data primarily reflect the structural trends in central government policy and in the Chinese economy outlined in Part I, above, including: large expansions in zero-carbon energy generation (capacity and output) and the increased use of natural gas in electricity generation (see Appendix II, Table A2.1); the new restrictions on coal consumption, particularly in the key economic regions, associated with China's Airborne Pollution Prevention and Control Plan (State Council, 2013); slow growth (in 2014) and decline (in Q1 2015) in heavy industrial production and hence in industrial electricity demand (see discussion of industrial emissions in Chapter 4.2, below); and increased efficiency in the use of

34 Some observers have raised the possibility of anomalies in the 2014 Chinese data on overall coal use (Wilson, 2015; Wynn, 2015). We address these concerns in Chapter 4.4, below, in the discussion of overall coal data. We think it unlikely that the electricity data for 2014 is anomalous, since electricity data is among the most reliable in China. Moreover, the electricity data are consistent with structural trends in the economy and policy; we see nothing to suggest that the 2014 electricity data are anomalous.

35 Electricity generation output grew 4% according to China's National Bureau of Statistics (2015a). This figure is consistent with Garnaut's forecast. The CEC (2015b) figures are, at the time of publication, the most recent and comprehensive (they decompose thermal capacity expansions into coal and gas), hence we use these throughout.

36 See calculations in Appendix II, Table A2.2, based on CEC (2015b) data. Compare Myllyvirta (2015b), who finds that coal-fired generation fell 1.6% in 2014.

37 In Appendix II, Table A2.2, we estimated that non-coal thermal generation grew by 15% in 2014 compared with 2013. Making the rough assumptions, for illustrative purposes, that non-coal thermal generation was smooth across quarters in 2014 and grew by the same rate in Q1 2015, we can infer that coal-fired generation would have fallen by 4.7%.

38 According to data from China's National Energy Administration, the intensity of coal use in electricity fell from 315 grams of coal-equivalent per kilowatt hour to 308gce/kWh, year-on-year (see NEA, 2014; NEA, 2015b).

39 Taking the (illustrative) fall in coal-fired generation of 4.7% compared with 2014 Q1 (see footnote 37) and assuming a 2% gain in the efficiency of generation, then coal use in power generation would have fallen by nearly 7%.

coal in power generation, associated with China's industrial energy conservation efforts. These structural trends are likely to continue, and if anything accelerate, as China's new development model increasingly takes hold, as the large overcapacity in China's heavy industrial sector (which accounts for 60% of China's electricity demand: CEC, 2015a) presages further production cuts in those sectors, and as investment more generally falls as a share of GDP (CCICED, 2015; Garnaut, 2014; Anon., 2015a).

In and of itself, the 2014 and Q1 2015 data does not conclusively show that coal use in electricity *peaked* in 2013. Below we consider four possible reasons why it could rise again in future, and then draw our final conclusions.

4.1.1 Cyclical variability in hydrological conditions and hydroelectric output

One reason coal use in electricity may increase in future has to do with cyclical variations in hydroelectric output. Hydroelectric output depends partly on hydrological conditions that vary from year to year. Since hydroelectric capacity tends to get used ahead of coal-fired power capacity, variations in hydroelectric output are transmitted inversely into thermal (including coal-fired) generation output (Garnaut, 2014).

Average hydroelectric running hours are 3405 hours per year of installed hydro capacity.[40] Hydrological conditions in 2014 were favourable and hydroelectric plants were utilised for 3653 hours — 248 hours more than the average — resulting in an estimated additional 72 terawatt hours (TWh) of electricity being generated from hydro sources.[41] Given that coal-fired power generation output fell 57TWh in 2014,[42] this implies that, controlling for the yearly variation in hydrological conditions, coal-fired power generation increased in 2014, but by a mere 15TWh compared with 2013 — or less than half of one percent of total coal-fired generation output in 2014.[43] Given that the coal-fired generation fleet became more efficient in 2014 (CEC, 2015b), likely by somewhere between 0.6% and 1.5%,[44] we can conclude that coal use in power generation likely fell slightly in 2014, even when controlling for hydrological conditions. Since these data are subject to a degree of uncertainty, we draw the more cautious conclusion that coal use in electricity reached a maximum point in 2013 or 2014, controlling for hydroelectric variability, hence our phraseology of "a structural maximum in 2013/14".

40 Average running hours calculated based on yearly average running hours for the last seven years, from 2008 to 2014 (inclusive), as reported by relevant central government agencies: see Appendix II, Table A2.3.

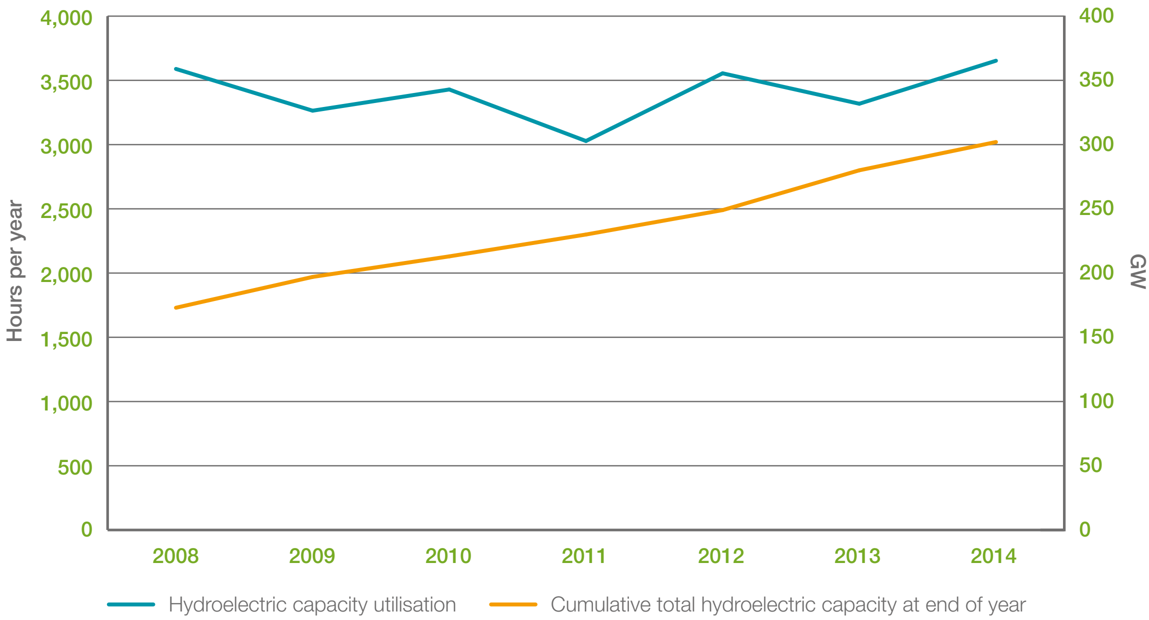
41 Hydroelectric capacity was 280GW in 2013 and a further 21.85GW was added in 2014 (CEC, 2015a). We multiply the 248 hours of "above-average" generation by each of (i) the 280GW total capacity as at the end of 2013 and (ii) 10.925GW (reflecting the capacity at the end of June 2014 assuming capacity expansions were spread evenly over the year, so as to account for the cumulative installation of capacity throughout 2014): 248hrs x (280GW + 10.925GW) = 72,149GWh (which we round to 72TWh) of "above average" hydroelectricity generated in 2014.

42 See Appendix II, Table A2.2.

43 On CEC (2015b) data, the additional coal-fired generation output (controlling for hydro variability) of 15TWh amounts to 0.4% of the 3957TWh of coal-fired power generated in 2014 (see Appendix II, Table A2.2).

44 China's 12th Five-Year Plan suggests that that the amount of coal per megawatt hour of coal-fired electricity generated will continue to fall by an average of 0.6% per annum; Mai and Feng (2013) suggest a rate of fall of 1.5% per annum and Garnaut (2014) assumes a fall of 1% per annum. This is due to the replacement of older, less efficient capacity with newer, more efficient capacity (see, e.g., CEC, 2015b).

Figure 4. Hydroelectricity in China — capacity utilisation and expansion



Source: Data from Chinese government agencies (see Appendix II, Table A2.3 for data and sources).

4.1.2 "Backloading" of non-coal generation capacity across five-year plans

Another possible reason that coal use in electricity generation could rise again in coming years has to do with the tendency for capacity additions of non-coal energy sources, which are the subject of planning targets in China's five-year plans, to occur unevenly across plans. Typically, capacity expansions occur disproportionately toward the later years of five-year plans in a bid to ensure the applicable targets are met — a phenomenon sometimes referred to as "backloading". For example, deployment of renewable energy sources in 2014 was considerably higher than in the preceding three years, and could well be relatively high again in 2015 (the final year of the 12th Five-Year Plan). In contrast, we could expect to see non-coal generation capacity expanding at a slower rate, other things being equal, in the early years of the 13th Five-Year Plan (but expanding at a faster rate in the final years of the Plan), such that coal-fired generation output (and hence coal use) would need to expand to fill the gap in incremental electricity demand in the early years.

However, other things are not equal: there are now many structural factors driving the expansion of non-coal energy sources and reductions in coal-fired generation that were not present in the early years of the 12th Five-Year Plan, which could well mean we see continued high growth in non-coal energy generation capacity in the years ahead, making it difficult to disentangle structural from cyclical expansion.

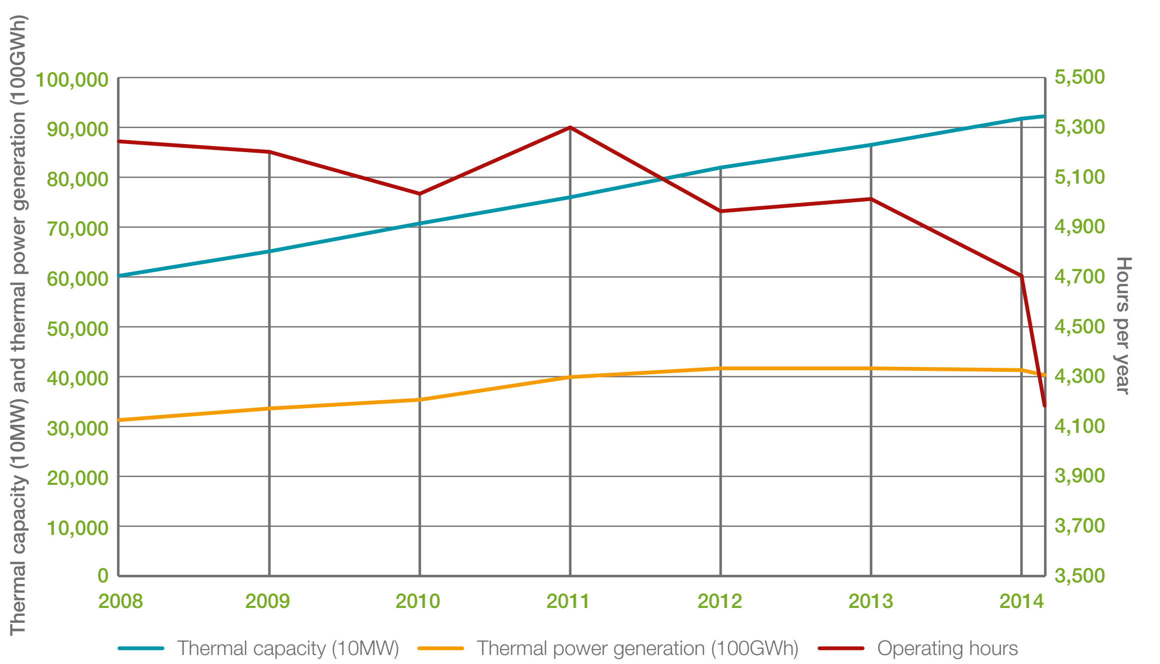
In any event, insofar as any rise in coal use in the early years of the 13th Five-Year Plan can reasonably be attributable to "backloading" we consider any such rise to be cyclical in nature, not structural.

4.1.3 Continued coal-fired generation capacity expansions, including "coal bases"

China added some 36GW of coal-fired power generation capacity to the electricity grid in 2014 (CEC, 2015b).[45] A number of analysts have pointed to the ongoing expansion of China's fleet of coal-fired power plants as evidence that China's coal use in electricity will rise in future, or will at least plateau for a very long time (Cohen and Liu 2013; Cohen 2015; Trembath 2014). But the inference that usage will follow from capacity needs to be scrutinised.

It is eminently possible, in the Chinese system, that much of the new capacity will not be utilised. Already, much of China's coal capacity is underutilised: coal-fired generation capacity growth has outstripped coal-fired electricity output growth since 2011, and the utilisation rate has been falling since then, reaching a yearly low of 54% in 2014 (Myllyvirta, 2015b) and falling even further in Q1 2015 (see Figure 5, below, showing utilisation of all thermal power). The decline in coal-fired power generation is being driven by targets and policies to reduce coal consumption and expand non-coal energy sources, which are in turn driven by high-priority concerns about air pollution, energy security and climate change. The inference that coal-fired electricity generation will continue to rise runs counter to the clear direction of official Chinese policy and to structural changes in the economy. If coal-fired generation continues to fall while capacity continues to expand, then utilisation will continue to fall, meaning an increasing amount of economic value in coal-fired power generation will be "stranded".[46] (This is, to be sure, a significant economic problem — unproductive capital allocation will be a drag on China's economic growth — but the point here is that it would not imply an *environmental/climate* problem.)

Figure 5. Thermal power in China, 2008 to Q1 2015: rising capacity + flattening output = falling utilisation



Source: Myllyvirta (2015b) updated with Q1 2015 data, compiled from China Electricity Council statistical releases.

Note: Shows thermal power overall, not just coal power (other thermal sources, especially gas, have been growing, while coal generation output has been declining)

45 China also closed some coal-fired generation capacity in 2014, likely around 2GW, as discussed below.

46 As Myllyvirta (2015b) notes: "A new coal-fired power plant will still generate power and revenue even if there is overcapacity, as the lower capacity utilisation gets spread across the entire coal power fleet and across all power plant operators".

So what explains the continued expansion of coal-fired power plant capacity? Why invest if there is already an over-capacity problem? We consider three plausible explanations. We think the first two are likely the best explanations for much of the recent and ongoing capacity expansions, implying that much of this new capacity will not be utilised, though there is a risk of future capacity expansions in the Western regions (so-called "coal bases") that will be utilised.

i) Legacy effects of earlier decisions to expand capacity inefficiently

First, recent capacity expansions reflect an inevitable lag in the effect of changes in central policy and market conditions on planning, approval, investment and construction decisions in the Chinese power sector. The average time from planning approval (given by the National Development and Reform Commission) to commissioning of a Chinese coal power plant is 4–5 years. Thus, capacity expansions in 2014 would reflect approval, investment and construction decisions made between 2009 and 2011 i.e. when the old model of growth prevailed, before the extent of excess capacity became clear, and well before the new development model took deep root and substantial restrictions on coal were introduced to curb air pollution. A recent study by the Financial Research Institute of the People's Bank of China and Greenovation Hub, a non-governmental organisation, lends weight to this explanation. The authors found that bank loans to the coal sector (i.e. not only coal-fired generators), rose sharply from 2012 and more than doubled in 2013, when growth in Chinese energy demand remained high and coal firms were rapidly expanding (Chen and Stanway, 2015). Accordingly, we could expect to see a large amount of new coal-fired generation capacity come online in the next 2–4 years that simply reflects the outputs of a project pipeline that was heavily stacked in the period up to around 2013, when different economic and policy conditions prevailed.

Moreover, the 2014 capacity expansions to some extent probably reflect investment decisions that were inefficient, even when viewed from the perspective of 4–5 years ago, due to subsidies and other incentives for heavy-industrial investment, which encouraged excessive investment by state-owned enterprises, local governments and state banks (CCICED, 2014; Myllyvirta, 2015b; Chen and Stanway, 2015). These incentives, a feature of the old model of growth reflected in the 12th Five-Year Plan, persist today, which may explain why we see continued planning and investment in new capacity even in the last couple of years.

Taking these factors together, we would not be surprised to see considerable (inefficient) capacity expansions for much of the remainder of this decade. Clear signals and policies will be needed in order to change the expectations and practices of firms, banks and government authorities with a view to minimising this inefficient allocation of capital (Chen and Stanway, 2015; PBC/UNEP, 2015), and we discuss this further in Part III. The key point for now is that these explanations for the continued expansion of coal-fired generation capacity in general seem more plausible than the alternative explanation that capacity is being expanded so that total coal-fired generation output will rise.

ii) Fleet upgrades for efficiency purposes

Some of the capacity expansions reflect the replacement of older, less efficient plants that are being closed down with more efficient (super-critical and ultra-super-critical) models of plants that use less coal per unit of electricity generated, contributing to the increased efficiency of the overall generation fleet, and hence a net reduction in coal use (where the replacement capacity is utilised at the same rate).[47]

47 China likely closed around 2GW of coal-fired generation capacity in 2014, based on State Grid's 2014 target (CEC, 2015b; see also Garnaut, 2014). The rate of increase in the thermal efficiency of China's coal fleet has increased significantly over the last decade. Old coal fleet generating at about 25-30% thermal efficiency (in the 1970s) is being replaced by new fleet that is 35-45% thermal efficient (Citi, 2013).

iii) Western "coal bases"

Alongside the factors discussed above, coal-fired power capacity *and generation* could be expanded in future if China pursues a strategy of building coal-fired power plants in its Western regions whose output is exported to eastern cities via ultra-high-voltage transmission lines — so-called "coal bases" (Slater, 2014). This was one of three options for mitigating eastern air pollution presented in China's *Air Pollution Prevention and Control Action Plan* (State Council, 2013).[48]

This kind of development on a large scale is not inevitable. It would have the undesirable effect of exacerbating air pollution in the west, and there are pressures for China not to develop its poorer western regions along the lines of the old growth model, given the lessons it has learned in the east, and the much cleaner development path that is now open to these regions. Moreover, solar conditions are much stronger in the western regions and many of China's most innovative renewable energy companies have their origins in Xinjiang,[49] suggesting great potential for a Western energy strategy based much more strongly on renewables, particularly solar, including concentrating solar power as well as solar photovoltaic (PV) (see also ERI, 2015a). The ability to expand ultra-high-voltage transmission lines presents increasing opportunities for efficient transmission of renewable energy from the Western regions to Eastern cities (ERI, 2015a) which could be pursued instead of coal bases.

Nonetheless, expansion of coal bases represents one structural risk of increasing coal-fired power generation and associated coal use in future, and we factor this into our conclusion alongside the structural trends in the other direction that we have identified.

4.1.4 Growth in other sources of electricity demand

As China rebalances its economy away from heavy industry and toward household consumption and higher value-added industrial and commercial activities, we can expect electricity demand in these areas to grow. However, these sectors are much less electricity-intensive; their growing electricity demand will be greatly outstripped by falling demand from heavy industry (which comprise 70% of Chinese electricity demand) in the near and medium term (over the longer term, improvements in household energy efficiency and compact city planning be important to reducing electricity usage in these sectors — see Part III, below).

A further structural trend that could increase the rate of electricity demand growth in future is the progressive electrification of passenger transport (and of other processes such as heating and parts of industry). Electrification of transport is likely to increase over the next decade (see Chapter 4.3, below), but substantial levels of electrification of transport are unlikely to be reached until after 2020 (Garnaut, 2014). To the extent electrification of transport and other sectors does occur, this will increase electricity demand and, in turn, increase (or slow the decline in) coal-fired power generation output, holding equal the deployment of non-coal sources, but this is unlikely to be a major source of pressure on electricity demand for the foreseeable future. There is typically an efficiency gain associated with electrification (e.g. of transport compared with combustion engines), which puts downward pressure on emissions, though the net effect on emissions would also depend on the emissions-intensity of the power

48 The others were increased use of gas and increased use of non-fossil energy sources. The western "coal bases" strategy was promoted by President Xi during a meeting with central leaders on China's energy security strategy in June 2014, and it has been heavily promoted by prominent figures such as State Grid's CEO Liu Zhenya (Slater 2014). Already, according to Mou Dunguo at the Centre for Energy Economics at Xiamen University, "two AC and four DC UHV lines have been built to transmit electricity from these bases to loading centres in the east" (quoted in Slater 2014).

49 We thank Ross Garnaut for bringing the latter point to our attention.

supply. The more the power supply decarbonises over time, the greater the overall emissions reductions from electrification (see, e.g., IEA, 2011; Hausfather, 2009).[50]

4.1.5 Conclusion on electricity emissions

On balance, we conclude that developments in the years ahead will likely show that coal use in electricity reached a structural maximum in 2013/14. Cyclical factors (variations in hydrological conditions and uneven expansion of non-coal generation capacity across five-year plans) could well cause coal use in electricity to vary around this structural maximum for the next few years (and these variations should be controlled for, as we have done in our analysis above). The structural economic and policy changes we have identified could well lead to continued (structural) reductions in coal use in electricity of the kind witnessed in 2014 and Q1 2015. On the other hand, structural pressures to increase coal use from electricity (from the construction of coal bases and the electrification of transport and other sectors) could arise. Overall, in the period up to 2025, we think the downward pressures on coal use are more likely to dominate.

Coal is by far the highest source of carbon dioxide emissions in the power sector, hence we could expect power sector emissions roughly to follow trends in coal use. However, a full accounting of emissions from the sector needs to take into account growth in gas-fired power generation (the carbon dioxide emissions from which are around half those from coal). We address the role of gas in our overall conclusions on fossil fuel trends and peak emissions in Chapter 4.2, below.

4.2 Industrial sector

A similar story is bearing out in China's industrial sector. Like emissions-intensive electricity generation, emissions-intensive industrial production expanded at a rapid pace between 2000–13.[51] By 2013, China was producing half of the world's steel and nearly 60% of its cement (WSA, 2015; CEMBUREAU, 2015). But, as we explain below, production in both industries moderated strongly in 2014 and is now falling. We conclude that this is a structural trend that will, in combination with substitution away from coal-intensive production methods, cause coal use in these industries to decline in 2015 and beyond. Whether overall industrial coal consumption falls thus depends largely on the extent to which the coal-to-gas and, to a lesser extent, coal-to-chemicals industries are allowed to expand in the years ahead.

4.2.1 Steel and cement: peaking and declining output and coal consumption

As discussed in Part I, a very large share of China's GDP is constituted by investment in China's heavy industrial sectors, which are severely overcapacity (CCICED, 2014). The extent of excess capacity in China's steel and cement industries — the largest sources of industrial emissions — and the need for a structural turnaround in these industries are now widely recognised throughout the Chinese government and the industries themselves. The chairman of the China Iron & Steel Association (CISA), for example, stated in 2014 that "China's steel sector has already entered a period of peaking and flattening out" (Reuters, 2015a), and the association's Q1 2015 report underscores that both consumption and production have peaked and are declining (CISA, 2015).

Indeed, in 2014, China's crude steel production grew at its slowest rate this century, 1.2%, and cement production grew at only 2.3% (NBS, 2015a). In Q1 2015, cement production fell by

50 We do not consider here the second order effects, which could favour zero emissions sources. For example, expanded use of electric vehicles will raise the storage capacity on the grid, with beneficial implications for the use of zero emissions electricity sources.

51 Consider, for example, the rapid expansion of China's steel production over this period, from 128.5 million tonnes of steel in 2000 to 822 million tonnes by 2013 (WSA 2015). See Song and Liu (2013) for discussion.

3.4%, crude steel production fell by 1.7% and plate glass production fell by 6% (NBS, 2015b). The decline in production is a response to falling demand from China's construction and heavy manufacturing sectors (CISA, 2015), consistent with China's "new normal" economic conditions. Accordingly, the prospects for declining investment, rationalisation and falling production across such sectors in the context of China's new development model, foreshadowed by some authors in recent years (see, e.g., Garnaut, 2014), indeed look strong. The expected decline in steel and cement in 2015 and beyond will reduce the demand for coking coal and thermal coal in industry, respectively.

Some have suggested that global steel growth will support future growth in China's steel production, but this misunderstands the scale and importance of changes in China's domestic market and steel industry. China is by far the world's largest steel consumer, now accounting for nearly half of world steel demand, and the vast majority of China's steel production over the last 15 years has supplied this large and (until this year) growing domestic demand (Anon., 2015d). As domestic demand moderated in 2014, China's steel producers responded by rapidly expanding their exports, but this export expansion clearly has its limits: it has depressed global steel prices and has raised trade tensions in Europe and the US, with producers in those countries accusing China of dumping cheap steel and pressing their governments for protectionist responses (Anon., 2015d). Accordingly, China's own steel industry body expects a decline in Chinese steel exports in future, after the 2014 spike (CISA, 2015), suggesting that consumption growth in export markets is unlikely to offset the decline in China's domestic market (see also Anon., 2015d).

The downward pressure on direct coal use in industry resulting from falling steel and cement output is being compounded by trends within these industries to substitute away from emissions-intensive production processes. A declining proportion of steel, for example, is being produced from blast furnaces (which use coking coal), which are increasingly being substituted for methods that use recycled scrap steel (which do not use coal). In combination with plateauing production, this trend caused coal use in steel production to fall 1.5%, and coal use in the construction materials sector (including cement) to fall by 0.2%, in the first 11 months of 2014 according to the China Coal Industry Association (Anon., 2015c). Industry leaders not only expect steel production in China to fall strongly throughout 2015 (recall it fell 1.7% in Q1) (Serapio, 2015), but also a greatly increased proportion of production to come from recycled scrap methods, with the result that China's coking coal demand is likely to drop significantly in 2015 and, looking further ahead, it has likely entered a declining trend of at least a couple of percent per annum.[52] A similar trend of levelling-off and decline in output, and substitution toward lower-emissions processes, is occurring in the cement industry.[53]

Steel and cement production are responsible for around 70% of China's industrial emissions, meaning declines in coal use from these sectors will put significant downward pressure on China's industrial (and overall) emissions from coal.

4.2.2 Coal to chemicals and coal to gas: risks of expansion

Against this, coal use in some other heavy industrial sectors is growing, or at risk of growing, in the years ahead. One is the chemicals industry, which is rapidly expanding its coal use, albeit off a relatively low base (Anon., 2015c). In February, Macquarie projected growth of coal use in chemicals by 130MT by 2020 (Macquarie Research, 2015), which could offset a significant portion of the expected reduction in coal use from steel and cement.

52 Ross Garnaut (pers. comm., March 2015).

53 Ross Garnaut (pers. comm., March 2015).

A second type of industrial coal development being considered in China is to build large-scale coal-to-gas plants in Central and Western coal-producing regions and export the resultant synthetic natural gas (SNG) to Eastern cities for consumption in gas-fired electricity, heat or industrial production (Slater, 2014). This would displace air-polluting coal-fired power stations with lower-polluting gas, but the SNG plants would add greatly to industrial coal consumption and water consumption, and to the lifecycle GHG emissions of the energy ultimately consumed, since the process of converting coal to SNG is extremely energy, water and GHG intensive.[54]

Two SNG plants are currently in operation and, as of July 2014, there were 48 projects in the pipeline (Ottery, 2014). According to an analysis by Greenpeace, if all 50 projects were to proceed and be operational by 2020, they would produce 225 billion cubic metres (bcm) of SNG and 1.087GT of carbon dioxide per year (Ottery, 2014). This would clearly add greatly to China's industrial coal consumption and carbon emissions, and would tend against both an early emissions peak and strong emissions reductions post-peak. In our view, the industry is unlikely to expand at anywhere near this scale, given the economics of the industry, the implications for water use and GHG emissions, and likely tendencies in Chinese policy. Though even the target for the sector previously set by China's National Energy Administration, of 50 bcm of SNG per year by 2020, which would produce around 242MT of carbon dioxide per year (Ottery, 2014), would probably prevent China's industrial emissions from peaking by that time.

In December 2014, Chinese press reported that the government was considering adopting in its 13th Five-Year Plan a policy of refusing approvals for new coal-to-SNG plants, thus limiting coal-based SNG production capacity to 15 bcm at the end of the decade (Liu, 2014). This would limit emissions to 67.5MT of carbon dioxide per year (Liu, 2014). In our view, such a moratorium would be much more consistent with the early peaking, and strong decline, of industrial coal and emissions and therefore desirable from the perspective of climate mitigation (as well as water security). It would also send a clear signal to the international community about the importance China places on climate change mitigation as an independent issue, distinct from mitigating local air pollution.

Nonetheless, for analytical purposes, the expansion of this industry remains a risk that must be factored into emissions forecasts.

4.2.3 Conclusion on industrial emissions

We have not analysed in detail data on emissions from all industrial processes, however we have analysed the key trends in the industries responsible for the bulk of China's industrial coal use and associated emissions, and find that both output and coal use in these industries has peaked and entered into a structural decline. Against this, expanded coal use in the chemical sector could offset much of these reductions in the next five years. Combined with a modest increase in SNG production (in our view more likely than a large increase), we could expect industrial emissions roughly to plateau over the next five years, with reductions after that time dependant largely on policy. Though a large increase on SNG production, which would add greatly to China's industrial coal use and emissions, is unlikely, it cannot be ruled out at this stage. Our overall conclusion is that, like coal use in power, coal use in industry is plateauing, with net declines more likely than net increases over the next 5–10 years.

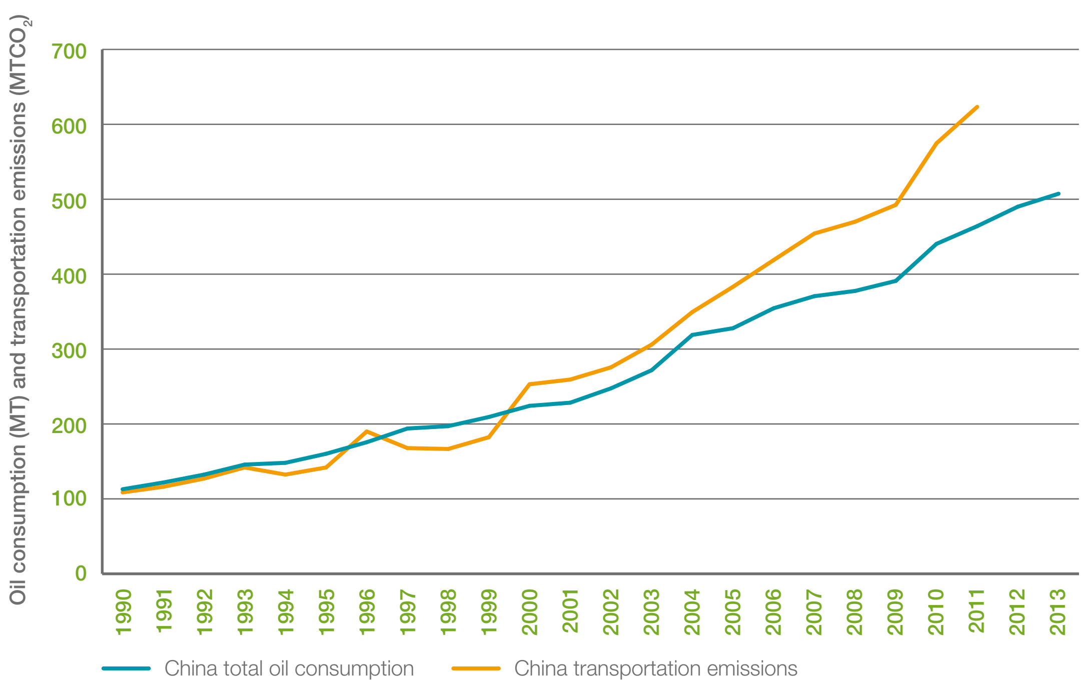
54 A recent study by researchers from Duke University and published in Nature found that the lifecycle GHG emissions of SNG used to produce electricity are ~36-82% higher than for pulverised coal-fired power generation (Yang and Jackson, 2013). The study also found that, compared with shale gas production, the life-cycle GHG emissions of SNG production (i.e. not including downstream uses), are seven times higher and the water used in SNG production is 50-100 times higher (Yang and Jackson, 2013). See also Ding et al. (2013).

4.3 Transport sector

Transport emissions are likely to continue growing over at least the next decade, from a relatively low base today. Nonetheless, existing and planned policy measures are likely to result in more moderate growth than commonly projected in many studies conducted over the past decade.

Total oil consumption (most of which is from the transport sector) and carbon dioxide emissions from transport have grown rapidly over the last quarter-century (Figure 6, below), driven strongly by growth in the road transport vehicle stock (in turn driven by rising population and per capita wealth) (Gambhir et al., 2015; 2 below).[55] In the period 2000–2011, oil consumption grew at an annual average rate of nearly 8%, but appears to have moderated somewhat in 2012–13 (BP 2014; Figure 4.3, below). Carbon dioxide emissions from transport in 2011 were around 620MT, or roughly 6% of China's overall GHG emissions, according to WRI's CAIT database (WRI 2014).[56]

Figure 6. China total oil consumption (all sectors) and CO_2 emissions from the transportation sector



Source: BP (2014) (oil consumption data); WRI (2014) (CO_2 emissions from transport data).

55 CO_2 emissions from road transport constitute roughly 80% of China's domestic transport CO_2 emissions, or roughly three-quarters of all of China's transport CO_2 emissions including international shipping and aviation emissions, based on IEA data for 2012 (IEA, 2014b).

56 The actual figure could be somewhat higher: compare data from IEA (2014b), showing China's 746MTCO$_2$ emissions from all transport, including international bunker fuels, in 2012 (2011 IEA data and 2012 WRI were not available for a same-year comparison).

Table 2. China's vehicle stock and associated energy consumption and carbon dioxide emissions

Year	Vehicle Stock (millions, excluding motorcycles)[a]	Energy consumption (PJ)[b]	CO_2 emissions ($MTCO_2$)[b]
2002	20.1	2636	186
2003	23.3	2876	203
2004	26.3	3149	222
2005	30.9	3395	240
2006	36.1	3613	255
2007	42.4	4032	284
2008	49.6	4773	336
2009	62.8	5485	387

Source: reproduced from Gambhir et al. (2015).

Notes: a sourced from Huo and Wang (2012); b sourced from Ou et al. (2010).

There is considerable uncertainty over the trajectory and size of China's future transport sector and associated carbon dioxide emissions, as these depend on a diverse range of economic, technological, social and policy factors affecting both supply and demand. Some studies, undertaken in the context of the old growth model, project high future growth in vehicles and oil consumption (which would drive significant growth in carbon dioxide emissions).[57]

However, cognisant of the dangers associated with continued strong growth in vehicle use and oil consumption — energy insecurity, traffic congestion, air pollution and rising GHG emissions — the development of policy responses in this area has become a major topic of discussion and action among Chinese policy-makers. China's 12th Five-Year Plan includes tougher policies for reducing energy consumption and emissions in the road transport sector, especially through improvements in the efficiency of combustion engine vehicles (Huo et al., 2012; Gambhir et al., 2015). Current policy is to strengthen fuel economy standards for passenger vehicles progressively over the next decade, to reach levels close to those of the world leaders — the EU and Japan — by 2020, while also incentivising the production of and demand for new energy vehicles, including electric vehicles, with the latter likely to be increasingly emphasised in the 13th Five-Year Plan (Gambhir et al., 2015; Chinese Academy of Sciences, 2009).

Taking into account existing policies, the IEA in its New Policies Scenario projects growth in Chinese oil consumption until 2040 at an average rate of 1.6% per year, with growth of around 2.4% per year to 2030, slowing to 0.4% per year in the subsequent decade and plateauing

57 See, e.g., Huo and Wang (2012) (forecast total vehicle stock in 2050 of 530–623 million); Hao et al. (2011) (607 million vehicles by 2050); Wang et al. (2011) (450–550 million vehicles as early as 2030). But compare Ou et al. (2010) and Jiang et al. (2010), both of which involve studies undertaken at a similar time to the others mentioned here, which project relatively lower vehicle stock growth, reaching around 500 million road vehicles by 2050. All projections referred to in this footnote exclude motorcycles. Ou et al. (2010) and Jiang et al. (2010) have both projected about 115–120 million motorcycles in China by 2050.

around 2040 (2014a, 100, 654).[58] But given the rapidly changing policy environment in the context of the new development model, these projections could be seen as overly high.[59]

In light of Chinese trends in vehicle technology development, urban planning (which affects transport demand) and policies concerning air pollution, congestion, and innovation, scholars are now exploring deeper decarbonisation scenarios for the transport sector (Gambhir et al. 2013; Gambhir et al., 2015; Huo et al., 2012).[60] Gambhir et al. (2013), for example, project transport sector carbon dioxide emissions under a hypothetical business as usual (BAU) scenario to grow to about 1.9GT in 2050, but which could be almost halved to less than 1GT by 2050 through new policies and measures.[61]

While making firm projections of emissions trends in the transport sector is difficult, we think more moderate growth in transport emissions, along the lines discussed in the previous paragraph, are more likely over the next decade, given current trends in policy and innovation. Nonetheless, stemming the growth, and then peaking and reducing, transport emissions over the next decade or so will be very important to China's ability reduce its overall emissions. As noted above, the electrification of transport holds the key to decarbonising much of the transport sector.

4.4 Conclusion: peak emissions

One means of gauging the likely peak of China's overall emissions is to consider trends in the consumption of fossil fuels (across all sectors). Coal accounts for two-thirds of China's primary energy consumption,[62] and the largest source of China's emissions. In 2014, China's coal consumption fell 2.9% to less than 4 billion tonnes of coal (and coal imports fell 10.9%), according to official Chinese preliminary statistics (NBS, 2015a).[63] In Q1 2015, China's coal production fell 3.5% year-on-year, and imports fell 45%, according to the China National Coal Industry Association (Xinhua, 2015c), suggesting[64] that coal consumption overall fell significantly — perhaps by around 4–5% year-on-year — which is consistent with data on coal use in the power and industrial sectors over this period discussed above.

58 The IEA (2014a) observes that: "In China, where security of oil supply is an important strategic issue, a combination of transport policies – notably fuel-economy standards – and slowing growth in industrial production and population (the latter peaking in the 2030s) have a large impact on the growth rate of oil consumption in China. Ninety percent of the total increase in oil demand occurs prior to 2030, after which average growth is only 0.4% per year."

59 The recent fall in the global oil price is unlikely to greatly effect China's oil consumption due to price controls on fuel products. The recent surge in oil imports, prompted by the lower prices, has been directed primarily toward filling strategic reserves. Meanwhile, as consumer demand moderates, China has grown its export of refined products (Hornby et al., 2015).

60 Gambhir et al. (2013) assume, in their baseline scenario and in their low-carbon scenarios, around 270 million cars and vans in China by 2050 (with total road vehicles, including motorcycles, of 440 million) — significantly lower than earlier projections (see footnote 57, above). This is because they assume "more 'Japanese' patterns of growth towards high urbanisation levels with mixed use zoning and high capacity public transport infrastructure" (at 620). They performed a sensitivity analysis on their transport sector emissions results by substituting an assumption of 500 million road vehicles in China by 2050 (excluding motorcycles), which they find would lead to an additional 300MTCO_2 emissions by 2050 compared with their low-carbon scenario (at 622–624). Compare Gambhir et al. (2015), which uses higher assumptions of road vehicle stock for both BAU and sensitivity analysis.

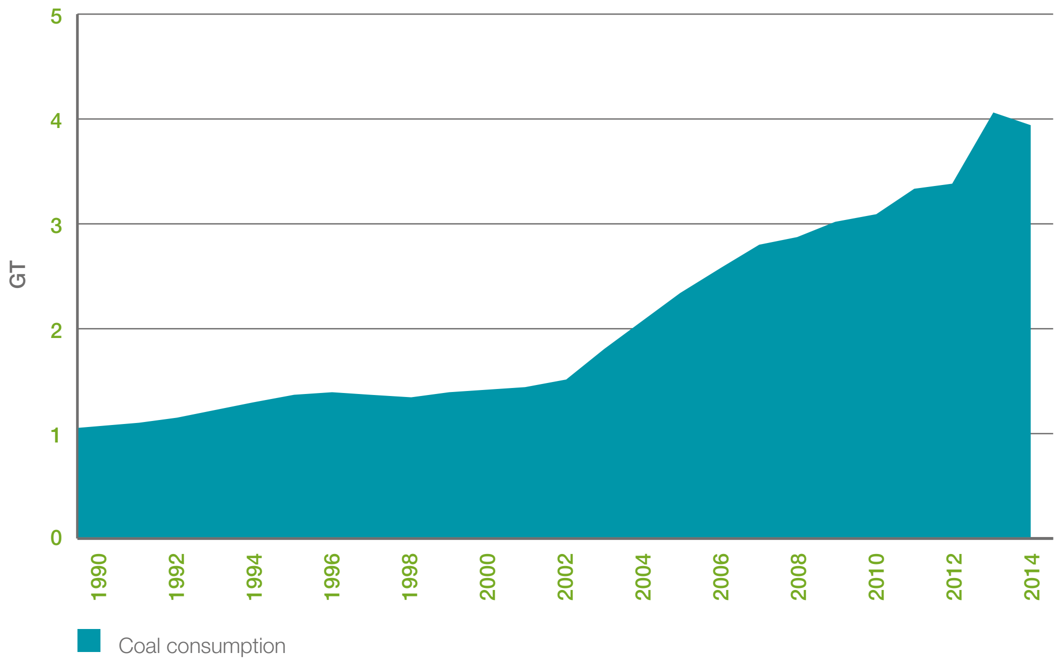
61 Gambhir et al. (2015) model the road transport sector only, in greater detail. In that study, they assume higher growth in road transport than in Gambhir et al. (2013). In the 2015 study, their BAU scenario projects road transport emissions peaking at just over 2GTCO_2 around 2050, and in their low-carbon scenario road transport emissions peak at around 1.7GT and decline to around 1.2GT by 2050.

62 Coal's share of energy consumption was 66% in 2014 according to official Chinese statistics (NBS 2015a).

63 See also figures from the China Coal Industry Association and the National Energy Administration, which recorded falls in Chinese coal consumption, production and net imports (Xinhua 2015a; Xinhua 2015b; CPNN 2015; Myllyvirta 2015c).

64 It is not yet possible to calculate the exact fall in consumption without knowing how much China's coal inventories changed.

Figure 7. Total coal consumption in China, 1990–2014



Source: NBS (2015a)

Note: see footnote 66, below, which explains why coal use appeared to jump significantly in 2013; in fact, coal use in 2009–2012 was likely higher than represented in this figure, giving a smoother increase over this period up to 2013.

Some observers have raised the possibility of anomalies in the 2014 coal use data (Wilson, 2015; Wynn, 2015). However, in light of our analysis of coal use in electricity and industry above, and noting that electricity and industry each account for about 50% of coal use, we think China's coal use did fall in 2014, though perhaps by more like 1.5%. Since we conclude that coal use in both sectors has reached a structural maximum, we expect coal to plateau (possibly with some cyclical variations around that point over the next five years), but with the balance of possibilities pointing toward a decline trend in the years ahead.[65] While it is theoretically possible that the 2014 data are seriously anomalous as suggested by the above-mentioned authors, we think this is unlikely, given that the structural trends in the economy and policy, and multiple independent lines of data, paint a compelling and consistent picture of structural peak and plateau or decline in coal use in both electricity and industry.[66] More comprehensive statistics (due to be released later in 2015) will provide more authoritative and precise data, however we would be surprised if they altered our qualitative conclusions.

Estimates of a peak date for China's coal have been moving ever earlier over the last few years. A 2020 peak would have seemed highly implausible five or ten years ago. Even 12 months ago, when we argued that China could peak coal by 2020 (Green and Stern, 2014), this was

65 This prediction is subject to the caveats mentioned above in relation to coal use in electricity and industry.

66 We note, however, that the most recent Chinese statistics (NBS, 2015a) significantly revise upwards the data for total coal consumed in 2013 — from around 3.5 billion tonnes to over 4 billion tonnes — on the basis of the one-in-five-year economic census that was carried out in 2014, which puts the 2013 data on a much firmer footing (see Myllyvirta, 2015a for discussion). At the time of publication, China's statistical agency had not yet released revisions for the few years preceding 2013, which we can expect would raise the coal use figures for those years in similar proportion to the 2013 revision. This explains the seemingly anomalous jump in coal use in 2013 in Figure 7., above; in reality, the growth in 2013 was likely relatively slow, because 2012 coal use would have been higher than reflected in Figure 7.

considered a minority view. That coal may have already peaked — and has, in our view, at least reached a structural maximum and plateau — is a measure of the extraordinary pace of change in China, and reflects the many structural economic and policy shifts that we have discussed.

Furthermore, peak coal consumption is regarded as a leading indicator of peak emissions, at least of carbon dioxide — the question is, leading by *how long?* This is not an area where precision is possible; assumptions need to be made. We can expect carbon dioxide emissions from natural gas and oil to continue rising, perhaps for another decade or more (albeit at slowing rates), as overall energy consumption continues to grow, as gas is promoted as a substitute for coal in energy production, and as the transport sector expands. Coal use is currently a very large driver of China's energy (and overall) emissions, whereas oil and gas contribute relatively small shares, so even a modest fall in coal use drives a large reduction in absolute emissions, whereas high growth in oil and gas contribute a relatively small, but growing, amount of absolute emissions. The NCE China Study finds a ten-year lag between peak coal and peak carbon dioxide emissions. If the assumption of a ten-year lag is appropriate, we would expect a peak in Chinese emissions in the mid-2020s.[67]

In our view, based on our analysis of trends in China's new development model, and in the key sectors considered above, it is highly unlikely that China's emissions will peak as late as 2030. It is much more likely that they will peak by 2025. The plausibility of this prediction is strengthened by the coal use, electricity and industrial data from the first quarter of 2015 discussed earlier. Indeed, the peak could well come earlier than 2025. In Appendix III, we present an illustrative scenario in which China's carbon dioxide emissions from energy peak by 2020, explaining the underlying assumptions to illustrate how this could happen.[68]

Trends and levels of carbon dioxide emissions in China's land-sector, and in its non-carbon dioxide emissions (from all sectors), are less clear, and we have not analysed these for present purposes.[69] They represent a relatively small proportion of China's overall emissions (around 25%).[70] Hence we assume that the peak in carbon dioxide emissions from energy will largely determine the peak in overall emissions.

Were China's emissions indeed to peak around 2020–2025, it would be reasonable to expect a peak emissions level of around 12.5–14GT (assuming emissions in 2014 were around 12–13GT and emissions growth is slowing rapidly, if not already negative).[71]

The trend in energy emissions beyond the next 5–10 years depends significantly on policy and its implementation, in particular: measures to achieve strong reductions in coal use/emissions; measures to moderate the growth in, and peak, transport emissions; and measures to moderate the expansion of gas consumption beyond the medium term (5–10 years). Discussion of these and other measures is the focus of Part III.

67 Since we think coal is plateauing, there is no clear, precise "peak" date for coal.

68 We also discuss assumptions about GDP growth and energy intensity reductions in Appendix III.

69 The NCE China Study assumes that non-CO_2 emissions (especially CH_4 and N_2O from the agriculture sector, and HFCs and N_2O from industry) will grow more slowly than CO_2.

70 China's land sector is already a net sink for emissions, and China is pursuing policies that would expand that sink capacity further still (see NDRC, 2013), which will also push overall emissions toward an earlier peak date.

71 Precise calculations of China's emissions are not available. Leading databases, WRI (2014) and the IEA's emissions database (IEA, 2015a), differ in their estimations by more than 1GT for emissions in 2010, with the former at the lower end (9.4GTCO_2e, including land-use and forestry) and the latter at the higher end (10.8GTCO_2e, including land-use and forestry). More recent direct comparisons between the two datasets are not available. The assumed 2014 emissions range of 12–13GT is based on multiple data sources containing more recent (2013) estimates of CO_2 emissions (e.g. Global Carbon Project, 2014) and assumptions about non-CO_2 emissions growth based on previous ratios of CO_2 to non-CO_2 emissions. The higher end of these estimates is more likely to be accurate in light of the upwards revisions to China's coal statistics in the years leading up to 2014 (see footnote 66, above).

Part III — Achieving rapid emissions reductions, post-peak

Reducing China's greenhouse gas (GHG) emissions rapidly after they peak will be crucial to reducing global emissions, and hence to China's long-term development interests. Achieving strong improvements in air quality, water security and energy security, and economic gains from increasing productivity, clean innovation and leadership in global markets for clean goods and services — all of which would accompany the efforts needed in the years ahead to enable rapid reductions in post-peak emissions — will be crucial for China's economic interests in the medium term (CCICED, 2014; GCEC, 2014b; Green and Stern, 2014; Teng and Jotzo, 2014).

Yet, achieving rapid declines in post-peak emissions will present a significant challenge for China as it continues to grow and urbanise. It will require, among other things, comprehensively deepening reforms in cities and in the energy system, supported by a concerted approach to clean innovation, green finance and fiscal reform. In other words, China's "new normal" will need to foster a dynamic process of structural transformation, in which sustainable growth, energy security, a clean environment and a steep decline in emissions all reinforce one another. The ongoing development of China's 13th Five-Year Plan presents an important opportunity to lay the foundations for this transformation.

5. Cities

The urban form and transport infrastructure of cities are extremely long-lived assets that create long-term path-dependencies with respect to land use, transportation, resource utilisation and GHG emissions (Rode and Floater, 2013; MGI, 2009). Given the extraordinary urbanisation that will occur in China in the coming 10-15 years,[72] the urban planning decisions and associated policy and investment choices China makes today and over the next decade will have long-lasting implications; they will determine whether China's cities are liveable, attractive, competitive and energy efficient.[73]

It will thus be critical that China's city planning be based on a model of spatially compact, medium/high density urban form, tightly linked by mass transit systems (Rode and Floater, 2013; GCEC, 2014a).[74] The power of such a model can be illustrated by a comparison between Atlanta and Barcelona, two cities with roughly the same population and economic size: Atlanta's carbon dioxide emissions from private and public transport are 7.5 tonnes per person; Barcelona's are only 0.7 (GCEC, 2014a). Moving strongly to compact models of urbanisation will be particularly important for restraining growth in China's vehicle stock and transport emissions,

72 China's urban population is expected to increase from around 700 million in 2013 to around 850 million in 2020, and to approach 1 billion in the late 2020s. World Bank (2015b; 2015c) data show China's urban population was 53% of China's total population of 1.36 billion in 2013. China's urbanisation plan targets an urban population of 60% by 2020 (Xinhua, 2014b), implying a total of around 850 million urban residents on the assumption that China's total population at that time will be around 1.4 billion.

73 As the effects of climate change increase, putting pressure on already scarce resources like freshwater, affecting food production, raising sea levels and worsening natural disasters, it will be critical that China's cities are also built to be resilient to these effects.

74 Further planning elements will be needed to make China's cities "people-centred" (see Chen et al., 2008; UCI, 2013). For China, this phrase connotes an emphasis on the provision of essential public services, particularly education and healthcare, and residential registration (hukou) reform (Xinhua, 2014b; CCCPC 2013).

which would otherwise risk becoming a major source of emissions growth in China (see Chapter 4.3, above).

Urbanising in this way will necessitate reforms to city-level fiscal and governance arrangements, so that the right incentives and revenue structures exist to support such a model of urban development and the social services accompanying it (see Ahmad and Wang, 2013; World Bank, and DRC 2014; Green and Stern, 2014).

6. Transforming energy systems

Another key determinant of China's ability to achieve a strong rate of fall of emissions, post-peak, will be the energy efficiency, and energy mix, of China's energy system. The relationships between energy supply, energy efficiency and economic output can be considered in terms of the emissions intensity of energy, and the energy efficiency of output (see Box 6.1 below). We consider energy efficiency (energy intensity) first and then energy supply (emissions intensity).

Box 2. Economic growth, energy and emissions — some key relationships

The relationship between an economy's economic output, energy consumption, and carbon dioxide emissions (from energy) can be expressed mathematically as follows:

(1) Em = (Em/En x En/y) x y

Where: Em = CO_2 emissions from energy consumption;
En = energy consumption; and
y = economic output

If Em/y is falling at b% and output is growing at c%, (1) implies that:

(2) The rate of growth of Em = (c – b)%. Hence emissions fall if b>c, and rise if c>b

This can be expressed as: The rate of growth of Em = (–b) + c

Further, the rate of fall of Em is the sum of the rate of fall of Em/En and En/y:

(3) –b = –(f + g)

Where: f = rate of growth of Em/En; and
g = rate of growth of En/y

There is also a question of whether *b* depends on *c* (or vice versa). For example, a vibrant economy with high investment and growth may carry more scope for discovery and creativity. Conversely, small falls in *b* might be an indicator of a lack of creativity/inventiveness, which could imply slower growth.

6.1 Energy efficiency

The energy intensity of China's economy has fallen strongly over the last three decades since opening-up. This desirable decline trend was reversed for a brief period during the early 2000s, but continued to decline steadily over the decade to 2013, thanks largely to energy conservation measures put in place during this period. The decline in energy intensity accelerated sharply in 2014, falling 4.8% on the previous year — significantly ahead of the government's target of 3.9%, and of the 2013 decline of 3.7% (NBS, 2015a; Reuters, 2015b). Slower growth in electricity demand and in overall primary energy consumption appear to be the primary causes of the decline, since overall economic output appears to have been fairly steady over these two years (World Bank, 2015a; CEC, 2015a). This augurs well for future improvements in energy intensity, providing an indication of what we can expect as the structural change associated with the new development model takes hold.

Nonetheless, the energy intensity of China's economy remains well above that of the most energy-efficient advanced economies, and continued urbanisation will put pressures on energy demand (Green and Stern, 2014; Teng and Jotzo, 2014). Strong and continuous improvements in energy efficiency will be central to China's efforts to reduce emissions post-peak, and reforms put in place in the near term will lay the foundations for those improvements. Continued expansion and implementation of mandatory energy efficiency standards for buildings, appliances and vehicles, measures to encourage the growth of the energy services industries, and the liberalisation of energy prices (discussed further below) will all be important.[75]

6.2 Transforming energy supply

There is perhaps no more important factor affecting China's future emissions trajectory than the transformation of its energy supply. Given the grave threat that coal poses to all aspects of China's "new normal" — to air quality and health, energy and water security, industrial modernisation, and climate change — there are strong reasons for China to scale-up non-coal energy sources, limit additional coal-based energy and industrial developments, and phase out existing coal as quickly as possible. We therefore discuss each of these below. A lower-carbon electricity sector also paves the way for radically lower emissions from various other sectors through electrification, and we discuss transport below.[76]

6.2.1 Scaling up non-coal sources

A key theme underpinning China's efforts to scale up non-coal energy sources is diversification. Having a diversity of non-coal sources of energy is important because it: enables the technical and economic potential of new energy sources to be discovered; contributes to energy security; and, reflects the different roles that different sources and technologies play within an integrated energy system. A diversity of energy sources is valuable for China, not only to replace coal in incremental electricity generation, but also to displace existing coal usage.

Within the current portfolio of non-coal energy sources, some sources, such as gas and hydroelectricity, are likely to play a stronger role in the medium term but a more limited role over the longer term. Other renewables and nuclear will therefore need to be expanded at an accelerating pace if coal is to be phased out.

Gas: China has targeted an expansion of gas in primary energy consumption to 10% by 2020, and it expects much of this gas supply to be used directly in households, industry and

75 See Green and Stern (2014) and references cited therein for further discussion of each of these measures and the mitigation potential of stronger energy efficiency improvements.

76 Electrification is a key pathway to reducing emissions in other sectors, especially transport, residential heating, and some parts of industry (Fankhauser, 2012; IDDRI/SDSN, 2014).

transport, along with significant development of gas for electricity production (State Council, 2014). While the prospects for expanding gas over this period look strong, there is much uncertainty, arising from both foreign and domestic factors, about China's ability to scale-up gas consumption beyond the next 5–10 years.

Much of China's incremental gas consumption over this period is likely to be supplied from imports, through pipelines from Russia and Central Asia, and in the form of seaborne LNG from various countries. While the growth in gas imports and associated infrastructure is strong (EIA, 2014), dependence on foreign sources, and associated energy security risks, could well constrain China's willingness and ability to scale-up imported gas supplies beyond this period.

At home, the picture is also a mixed one. On the one hand, China faces many challenges (e.g. geological, technical, regulatory and environmental) in scaling up its domestic shale gas industry (Gao, 2013; Gunningham, 2014; Stevens, 2014). The ambitious 2020 targets for shale gas production set by the government in 2012, of 60–100bcm were last year more than halved to 30bcm due to technical challenges (Platts, 2014). These obstacles and developments suggest that shale gas may not be able to make a major contribution to China's energy mix within the next 5–10 years. On the other hand, recent Chinese successes in exploiting tight gas (Chen, 2013) have raised the prospect that tight gas and, to a lesser extent, coal-bed methane production, could lift overall unconventional gas production in China to at least the 60–100bcm by 2020 originally targeted for shale gas alone (Granoff et al., 2015).

The many uncertainties in gas developments, particularly beyond 2020, underscore the importance for China of developing its gas supplies within a broader energy and climate strategy. The expected expansion of gas, if used as a substitute for coal and if it does not adversely affect the development of zero-carbon sources (and if methane leakage is managed and regulated appropriately[77]), should help to mitigate China's GHG emissions in the next 5–10 years (Granoff et al., 2015).[78] But if China is to reduce its emissions strongly post-peak, then the continued expansion of gas would become increasingly inconsistent with that goal. Accordingly, policy controls will be needed to limit the expansion of gas, beyond that period, to a role that supports a renewables-dominated system, through its application as idle back-up, or "firming", capacity (Granoff et al., 2015).

Hydroelectric: Hydroelectric power is also likely to contribute strongly to the expansion of non-coal generation in the next five years but be constrained beyond that, since China's capacity to increase large dam projects is limited by appropriate sites, and the best sites are increasingly being used up. While capacity continues to expand strongly, approvals for and investment in new dam projects have slowed in recent years, moderating expectations of future growth. Indeed, China revised down its official target for 2020 hydro capacity from 420GW to 350GW in its latest strategic energy plan (State Council, 2014; Reuters, 2014).

77 Whether electricity provided from unconventional gas, particularly shale gas, would be beneficial on a life-cycle emissions basis depends, among other things, on the degree of methane leakage in the production process, about which data are scarce (see Gunningham, 2014). At the very least, a robust regulatory regime involving minimum standards, rigorous monitoring, reporting, inspection and enforcement, will be necessary to control methane leakage to levels that preserve the climate-beneficial effect of gas relative to coal (see Granoff et al., 2015)

78 This will require policies to prevent coal from being inventoried or exported for use later or elsewhere, and insulating renewables from short- and medium-term competition with gas-fired developments (Granoff et al., 2015).

Other renewables: The bulk of non-coal generation expansion is thus expected to come from other renewable sources,[79] led by wind and solar, but with development also of geothermal, bio-energy and ocean energy. Solar and wind power capacity has expanded at astonishing rates in China in recent years, exhibiting strong technical progress and cost reductions (see Stern, 2015).[80] Critically, these and other renewable technologies have the potential to scale-up fast enough to displace increasing amounts of existing coal from China's energy mix over the coming decades, provided strong trends in energy efficiency (see above) continue to keep electricity demand growth low. China's energy planning agency has consistently revised upwards its planning targets for wind and solar PV generation capacity: in 2006, China planned to have 30GW of wind and 2GW of solar by 2020; with those targets long since eclipsed, China's latest 2020 targets for these technologies are 200–300GW of wind and 100GW of solar by 2020 (Jiang, 2014; State Council, 2014)[81] — around seven to ten times and 50 times higher, respectively, than the targets set eight years prior. With strong demand-side policies, such as feed-in tariffs, to support expansions at scale and continued innovation, we can expect costs to fall further and targets to continue to be revised upwards (CCICED, 2014).

A recent study conducted by the Energy Research Institute of China's National Development and Reform Commission, along with various Chinese partner institutes, demonstrates the technical possibilities, and the level and direction of official ambition regarding energy system transformation (ERI et al., 2015b). The study concludes that:

> "A high renewable energy penetration scenario in 2050 is both technically and economically feasible, in which renewables account for over 60% in China's total energy consumption and over 85% in total electricity consumption – signifying a true revolution of energy production and consumption…
>
> Wind power and solar power will become important pillars of the future power supply. Through technological breakthroughs, cost reductions as well as the comprehensively deepening of power sector reforms, between 2020 and 2040, wind and solar power will develop rapidly, with an average of annual newly installed capacity of close to 100 [GW]. By 2050, 2.4 [TW] of wind power and 2.7 [TW] of solar power will be installed, with a total annual output of 9.66 trillion kWh, which will account for 64% of China's total power generation and will become the main power source of the future green electricity system."

Nuclear: The other key source of non-coal energy with potential for significant expansion is nuclear. China is targeting an expansion to 58GW of operational capacity by 2020, and a further 30GW under construction by that time (State Council, 2014).[82] China currently has 21GW of nuclear capacity in operation (NEA, 2015b) and almost 23GW under construction (IAEA, 2015), meaning the 2020 target is unlikely to be met, though the capacity expansion will still be very large. Recent forecasts of Chinese nuclear capacity in 2030 range from 114–175GW.[83] On these forecasts, China would need to deploy around 100–150GW over the 15 years to 2030. France deployed 42GW in the seven years between 1980 and 1987, and the US also deployed large

79 The IEA (2014a), for example, in its New Policies Scenario, projects that China will install over 960GW of renewables-based capacity to 2040, and the bulk of new capacity and electricity generation will come from non-hydro renewables (2014a, 243–235, 654).

80 China installed a record 13GW of solar in 2013 alone (Stanway 2015), a further 10.6GW in 2014 (CEC 2015b), and is targeting a further 17.8GW, more than half of existing solar capacity, in 2015 (Bloomberg 2015).

81 The Chinese Academy for Engineering concluded that China's electricity grid could absorb these renewable energy power generation capacities in the short term (Jiang 2014).

82 China currently has 27 nuclear reactors in operation, 23 under construction, and more about to commence construction (IAEA 2015).

83 2030 forecasts for Chinese nuclear capacity included in this figure are: IEA (2014a, New Policies Scenario) — 114GW; WNA (2015) — 150GW; Wood McKenzie (2014) — 175GW.

amounts (30GW+) in two separate 3–4 year periods (Yip, 2014).[84] China is scaling up its nuclear capacity from a much larger economic and industrial base than the US and France had in the 1980s, and has two decades of experience building nuclear plants (Yip, 2014). Accordingly, China's ambitions look eminently achievable.

Grid/system management: The biggest challenge China may face in continued rapid expansion of these sources is the management of an increasingly complex energy system (IEA, 2014c). In particular, an increasing proportion of intermittent (wind and solar) and non-variable (nuclear) electricity sources generates challenges for the transmission and storage of energy and for the stability of the grid. Reflecting positively on China's ability to manage these issues, Garnaut (2014) explains that:

> "For many regions, the presence of large hydroelectric capacity which can be varied over short periods facilitates balancing the grid and can continue to do so. Over recent years, larger investments have been made in upgrading the electricity grid than the huge investments in generation, much of it to facilitate absorption of intermittent and non-variable power … [including] large pumped hydro storage facilities (a total of 30GW capacity to be installed by 2015) adjacent to many of China's large cities. Improvements in the grid and expanded storage facilities have facilitated more complete utilization of low-emissions capacity (People's Republic of China 2011)."

In future, increasing availability and lower cost of battery storage will provide further opportunities for storage, especially if China's plans for large-scale electric vehicle expansion succeed. This will be essential if the expansion of renewable energy sources is to occur at the levels necessary to achieve a relatively rapid phase-out of coal. At the same time, electric vehicle expansion will increase the complexity of managing the grid. This will therefore need to be an ongoing priority for China — and indeed for the world.

6.2.2 Limiting new coal developments

The second key factor in transforming China's energy supply away from coal is to limit any future coal-based developments through clear policy and planning signals, and regulatory controls.

Already, China has imposed limits on coal consumption and on the development of new plants in key economic regions (see Slater, 2014). However, in Chapter 4, we also identified three kinds of coal development that are occurring or being considered in China: ongoing construction and commissioning of coal-fired power generation capacity as a result of previous planning decisions and supported by perverse incentives for inefficient expansion; the construction of "coal bases" in China's western regions linked to eastern cities by high-voltage transmission lines; and coal-to-gas plants.

With regard to the first category, strictly limiting approvals for, and investments in, new coal plants — unless these are strictly necessary to replace older and less efficient capacity — will be needed to curtail these economically inefficient expansions (Chen and Stanway, 2015). Such action is strongly warranted for economic and financial reasons, let alone environmental, public health and climate reasons. In the case of coal bases and coal-to-gas plants, a strategic decision, reflected in the 13th Five-Year Plan, not to prioritise and support such developments, along with specific regulatory controls, would be consistent with achieving the kind of structural change, better growth and early peaking of emissions at the core of China's new development model.

84 The US deployed a total of 112 GW of nuclear power between 1957 and 1996, though much of this total came in waves of intensely active deployment: 38GW between 1972 and 1976; 33GW between 1984 and 1987; and a total of 93GW between 1972 and 1987 (Yip, 2014).

6.2.3 Phasing out unabated coal

The imperative to phase out coal leaves China with a challenge of managing its existing, large fleet of coal-fired power plants (which, as discussed above, is already under-utilised).

One option that may be available to some extent in the medium-term is to use carbon capture and storage (CCS) technology to abate the carbon emissions from coal plants. It will in large measure be the experimentation and deployment of CCS technology in China that determines its potential for application at scale and associated cost-reductions. Only if this proves successful could there be a case for maintaining coal (at least on climate mitigation grounds). The fact that CCS involves an energy penalty, of between 10-25% depending on the type of capture technology applied (EEA, 2011), means that coal plants with CCS require significantly more coal, and thus water use, than a conventional coal plant, giving rise to a trade-off between climate, energy security and water security objectives (Green and Stern, 2014).

These and other potential limitations of CCS technology mean that, even with a significant roll-out of CCS, China will likely face a significant stranded asset[85] challenge with regard to its coal fleet.[86] It will therefore be important for all relevant stakeholders in China — central and provincial governments, financial regulators, financial institutions (and other investors in Chinese coal assets), coal companies, coal-fired power generation companies, affected workers and communities — to undertake careful analysis and planning, and implement appropriate policies and practices, to achieve an orderly phase out of China's unabated coal fleet, mitigating financial risks and social impacts (Caldecott and Robins, 2014). Managing this transition well will be an important political and economic factor affecting China's ability to reduce emissions strongly, post-peak, and merits careful and immediate attention.

6.2.4 Transport

We highlighted in Chapter 4.3 the uncertainty around the trajectory of China's future vehicle stock and overall transport emissions. While existing policy, including tightening vehicle emissions standards toward world-leading levels, already suggests the potential for moderation in China's transport emissions growth, broader and deeper policy measures across the transport sector in the 13th Five-Year Plan and beyond will be needed in order to decarbonise China's transport sector. In transport, demand side measures are particularly important — including compact city planning, efficiency standards, and initiatives to change commuters' transport behaviour — some of which we have discussed above.

There are also many policy levers on the supply side, the most important of which is to promote the electrification of much of the transport system, with electricity supplied from an increasingly decarbonised electricity generation system. Scenario analysis conducted by Gambhir et al. (2013) demonstrates the high potential for carbon dioxide abatement from the full electrification of China's rail transport network (supplied with decarbonised electricity). Electric, hybrid and fuel cell vehicles will be important for decarbonising the road transport sector (Gambhir et al., 2015; Huo et al., 2012). And increasing use of lower-carbon biofuels will be necessary to reduce emissions from air, sea, and heavy-duty road transport (Gambhir et al., 2013). Support for innovation, both supply–push and demand–pull, will be important for the development and widespread diffusion (and associated cost-reduction) of the many different low-carbon vehicle- and fuel-types needed across the transport sector, as will the roll-out of network infrastructure.

85 Stranded assets can be defined as "assets that have suffered from unanticipated or premature write-downs, devaluations, or conversion to liabilities" (Caldecott, 2015).

86 To some extent, it may be possible to repurpose the thermal generation components of coal plants for use in concentrating solar thermal plants, which would mitigate the value of asset-stranding.

7. Key policies

We highlight here some additional policies that would help China to achieve the structural transition envisaged above.

7.1 Taxing coal and wider pricing reform

Expanded resource taxes, particularly on coal, would support all aspects of China's transition, directly and indirectly. Coal is currently taxed very lightly in China, and thus fails to tax coal resource rents to a reasonable degree, let alone to reflect coal's impacts on human health, the local environment and the climate (CCICED, 2014).[87] In addition to the normal reasons for taxation for revenue purposes (e.g. value-added tax, corporate tax etc.), it would be sound tax policy to rationalise existing ad hoc local fees and charges on coal, and to raise a centrally-administered tax on coal to reflect, at least to some extent: (a) an appropriate taxation of resource rent; (b) local environmental and health impacts from mining, transporting and burning coal; and (c) global climate impacts (Ahmad and Wang, 2013; CCICED, 2014).

Taxing coal in this way has a number of attractive features. It has lower complexity and administration costs than individual taxes or trading schemes for each component, particularly since the information needed to tax coal inputs is more easily obtainable by governments than is firm-level data on individual emissions (Ahmad and Wang, 2013). As such, it could be implemented more quickly and easier to administer, reducing the likelihood of "government failure".[88] In addition, the better availability of the relevant information and the upstream imposition of the tax make it harder to evade, thus it is likely to bring greater fiscal benefits when informal sectors are considered (CCICED, 2014; Bento et al., 2012).

A tax on the carbon content of coal alone of US$25/t$CO_2$ would add just under US$50 to the price of a metric tonne of coal. We have previously (Green and Stern, 2014) illustrated the potential incentive effects the tax could have and the revenue it could raise.[89] China's current low coal price and industry uncertainty over its future direction means that now is a good time to implement such a measure. To achieve this structural adjustment in an equitable an orderly way, and ameliorate some of its distributive consequences, the tax could begin at a relatively low level and be scaled up over time, and some of the revenues could be used to assist people on low incomes who are adversely affected (Green and Stern, 2014). Sharing revenues with local governments could also be important to elicit local information and compliance, and support for the reform in the first place, especially where less efficient local taxes are eliminated.[90]

A coal tax of this nature would be an important step in the Chinese government's wider energy and resource pricing reforms (CCCPC, 2013). Indeed, the full behavioural effect of such a tax on the demand side will only be felt with greater liberalisation of energy prices over time. Combined, these measures would have a significant effect on emissions reduction (CCICED, 2014). Moreover, they will help to prepare China's energy markets and governance systems for

87 CCICED's Task Force on Green Transition in China (2014) finds that the unit tax on coal is set at 8–20 RMB (US$1.29–3.22) per tonne for coking coal and just 0.3–5 RMB (US$0.05–0.81) for other types of coal.

88 This is not to deny that there will be significant political challenges associated with introducing such a tax.

89 The IMF has subsequently done its own analysis: it concludes that a coal tax of US$15/gigajoule would cut pollution-related deaths by two-thirds, substantially reduce CO_2 emissions and raise revenue of almost 7% of China's 2010 GDP (Parry et al., 2014).

90 We are grateful to Ehtisham Ahmad for helpful discussion of desirable Chinese tax reforms, including the political economy and administrative dimensions of such reforms. See further: Ahmad and Wang (2013) and Ahmad et al. (2013).

more complex approaches to carbon pricing over the longer term, such as the planned national emissions trading system.[91]

7.2 Green finance

Over the next decade and beyond, China will need to make very large investments in infrastructure in cities and energy systems (and in land-use systems) as its economy grows and population urbanises. Investing in infrastructure that is low-carbon, resource-efficient and environmentally-friendly — while diverting finance away from infrastructure that is highly-polluting, inefficient, and environmentally damaging — will be essential for China's sustainable economic development plans, and for global climate change mitigation. A recent study by The People's Bank of China and the United Nations Environment Programme found that "achieving the targets of moving toward a green economic development [model] and building an ecological civilisation requires an annual investment in [the] green sector of at least 2 trillion yuan (US$320 billion, or more than 3 percent of GDP) for the next five years" (PBC/UNEP, 2015, 5).

An influential determinant of whether green infrastructure attracts financing over higher-carbon alternatives will be the cost of capital. The cost of capital is particularly important for renewable energy infrastructure: even though the levelised costs of energy are often lower for renewable energy than for fossil fuel generation, it is more capital intensive (fossil fuel-based generation has lower up front capital costs but much higher operational costs due to the need to purchase fossil fuels). For newer and more innovative types of green infrastructure projects more generally, especially where these are dependent on government policy, capital costs also tend to be higher because investors perceive greater policy risks and may have less experience in financing such projects.

China's state development banking institutions are already playing a globally significant role in financing renewable energy at a low cost of capital (GCEC, 2014a). Indeed, such institutions are critical for facilitating green financial flows, since they can reduce perceived risks, share and pool risks, and build specialised skills in green infrastructure projects.

However, financing sustainable development in China will require a deeper and more comprehensive green finance strategy and institutional architecture over the next decade. The PBC/UNEP study referred to above sets out 14 detailed recommendations for establishing a green financial system in China spanning four categories: specialised investment institutions; fiscal and financial policy support; financial infrastructure; and legal infrastructure. These would go a long way indeed to providing the financial regulatory-institutional context needed for China's economic restructuring toward better growth.

7.3 Clean innovation

Reducing China's emissions strongly post-peak will require major efforts in zero-carbon energy innovation. This will require concerted Chinese policy and financial support across the full innovation chain in China (Green and Stern, 2014).

As we have discussed elsewhere,[92] China has a particularly important role to play in the middle of the innovation chain — demonstration and early-stage deployment of technologies with a high potential for emissions reductions and cost reductions. The size of China's internal market means it has a special advantage of *scale* when it comes to fostering the maturation of such

91 Combining, in an effective, efficient and equitable way, the multiple carbon and related policy instruments that China has implemented or is planning to implement will be a significant challenge, as it has been in Europe and elsewhere. This is an area where careful planning, informed by further research and analysis, is needed.

92 See Green and Stern (2014) and Boyd, Green and Stern (2015). See also GCEC (2014a) for further discussion of low-/zero-carbon innovation globally.

technologies. The partial application of revenues raised from coal taxes (and other environmental taxation) to finance support for green innovation is likely to be a potent policy combination for reducing emissions and fuelling economic growth.[93] Moreover, as China aspires to become a leader in zero carbon energy research and development,[94] many experts argue it will need to cultivate the strategic, institutional, financial, managerial and cultural conditions required for this kind of innovation (Cao et al., 2009; Cao et al., 2013; Segal, 2011; Wilsdon and Keeley, 2007; Zhi et al., 2013).[95] At the same time, smaller-scale technologies and more bottom-up and socially-driven approaches to green innovation should not be overlooked, especially given the potential for such forms of innovation to scale in other developing country contexts — the rapid expansion of e-bikes and solar water heaters in China being instructive cases in point (Tyfield et al., 2015).

8. Conclusion

China's "new normal" development model provides an extraordinary opportunity to ensure that China's growth is not only strong and sustained, but also low-carbon, more energy secure and less polluting.

Trends in the level, rate, structure and energy efficiency of China's economic growth, and in the mix of China's energy supply, ushered in strongly through policy developments in recent years, have already led to a remarkably rapid shift in the trajectory of China's greenhouse gas (GHG) emissions. As such, it is now possible to say with confidence that coal use in China has likely reached a structural maximum and begun to plateau. So significant is this turnaround that it was named by the IEA as the key factor that caused growth in global carbon dioxide emissions to stall in 2014, marking the first time in 40 years in which there was a halt or reduction in global carbon dioxide emissions that was not the result of an economic downturn (IEA, 2015b).

We also concluded that China's emissions are unlikely to peak as late as 2030, and are much more likely to peak by 2025. They could well peak even earlier than that. This suggests that China's international commitment to peak emissions "around 2030" should be seen as a conservative upper limit from a government that prefers to under-promise and over-deliver. It must be remembered that China's pledge includes a commitment to use "best efforts" to peak before 2030; we are beginning to see the fruits of China's best efforts.

While this paper has focused on China's domestic transformation to a sustainable economy, that transformation will have important repercussions throughout the world.[96] The United Nations Climate Change Conference in Paris later this year will be more successful if governments everywhere understand the extent of change in China, its implications for global emissions, and the positive impact that China's clean industrial development, investment and innovation plans are likely to have on global markets for clean goods and services (and the adverse implications for exporters of coal and certain other raw materials).

There are at least four important senses in which China has great influence over global emissions and over the developmental and economic choices that determine emissions.

93 See Green and Stern (2014) and references cited therein.

94 China's professed strategic ambitions to be a "world leader" in nuclear technology production and export through the engineering of "major technological breakthroughs" and "industrial upgrades" (Chen, 2014) illustrate China's growing appetite for more advanced energy innovation.

95 This is discussed further in Green and Stern (2014).

96 The international aspects of China's transformation are discussed by the authors in an accompanying paper: Boyd, Green and Stern (2015).

- First, its sheer size — geographically, demographically, economically and in terms of its energy use and GHG emissions — means China will always be a critical participant in global action on climate change.

- Second, China is seen by many developing countries as a model in the structure of economic growth and development, and as a leader in world economic affairs. As such, China influences the growth trajectories of many developing nations. Had China realised the difficulties of coal and inefficiently planned cities earlier it would likely have developed differently. It now has an opportunity to both tell and demonstrate to others the lessons it has learned about how to foster a strong economy while decarbonising and reducing local pollution.

- Third, China influences politics in rich countries. There is a lack of understanding in rich countries about the measures China has already taken, and its future plans, with regard to emissions. All too often, commentators and officials in rich countries highlight China's emissions as a justification for their own inaction. Continued strong examples of Chinese emissions reduction actions, clearly communicated to other countries, could silence such voices and lower the political barriers in rich countries to stronger climate action.

- Fourth, China's strategy for reducing emissions can set an example for all countries. China is combining regulation and direct energy conservation measures, support for low-carbon energy (including extensive investment from state development banks), and, increasingly, carbon pricing. China also plays a critical role in global supply chains for low-carbon technologies, including solar PV and wind. Increasingly, its scale and capacity for innovation in low-carbon technologies will make it a leader in the clean global economy.

Through these various channels of influence, China's actions on climate change have, more than any other country, the potential to steer global expectations, markets and policies toward the low-carbon economy. In this way, China's actions are likely to be self-reinforcing, with increasingly ambitious efforts on climate mitigation and low-carbon technology development triggering further actions and investments from others, in turn bringing down the costs of clean technologies and expanding markets for them, thus raising the benefits and lowering the costs to China of making that transition (Green and Stern, 2014). Eventually, this increasing momentum could unleash a large wave of clean energy investment, innovation and growth — a new energy-industrial revolution (Stern, 2015).

This is the only engine of domestic and global growth that can be sustained over the medium and long term — and China holds the keys.

Appendix I: New Climate Economy China Study (summary findings)[97]

This Appendix sets out the key findings of the Global Commission on the Economy and Climate's groundbreaking study, *China and the New Climate Economy* (GCEC, 2014b) (NCE China Study), discussed in Chapter 3, above.

Background to the New Climate Economy China Study

The NCE China Study is one of the country case studies produced for the NCE project to complement and deepen the Commission's flagship Global Report, *Better Growth Better Climate: The New Climate Economy Report* (GCEC, 2014a) (the NCE Global Report). The NCE China Study was produced by researchers at Qinghua University, which was also one of the eight affiliated research centres that had key input into the development of the NCE Global Report.[98] The involvement of the Qinghua research team in the Commission's work was extremely valuable and is an important example of China's growing global engagement on the issue of climate change.

The NCE Global Report provided independent and authoritative evidence on the relationship between actions that can strengthen economic performance and those that reduce the risk of dangerous climate change. The report focuses on the next two decades and shows that the ongoing structural transformation of the world economy in this period can be combined with action on climate change and can produce both strong, better quality growth and powerful acceleration of action on climate change.

China is a key country case study for the "better growth, better climate" concept, not only because of its size and its importance in tackling climate change, but also because other countries, less advanced in the structural transformation of their economies, will try to learn from China's experience. If China's policymakers had understood earlier the full effects of its coal-based, heavy-industrial development model, it is likely that China's development path would have taken a more sustainable path much earlier than now. There are important lessons, therefore, in both the NCE Global Report and the NCE China Study, for less developed countries and other emerging economies.

The NCE China Study demonstrates how, with the right policies, China can modernise its economy (achieving the structural change necessary to overcome the "middle-income trap" and become a high-income country) and achieve major improvements in energy security, local air pollution, and GHG emissions from the perspective of growth-climate interactions. The study was undertaken in 2013–14 and published in November 2014. As we discuss in Part II, above, the pace of change in China, even in the brief period since the study was undertaken, has been extraordinary.

Findings of the Study

Greenhouse gas emissions

The NCE China Study involved the modelling of scenarios for GDP growth, the energy sector (e.g. total energy consumption and energy mix), CO_2 emissions from energy, and local urban air

97 The authors are grateful to the research team at Qinghua University who produced the New Climate Economy China Study, led by Professors He Jiankun and Qi Ye, and to Teng Fei for his guidance on Appendix I.

98 See http://newclimateeconomy.net/content/research-partners.

pollution (SO2, NOx, volatile organic compounds, and particulate matter (PM) — both primary and secondary PM).

Rather than starting with a CO_2 emissions constraint such as a peak emissions level, the study models the emissions levels as consequences of assumptions about future economic growth and the emissions intensity of growth. These in turn depend on energy production and consumption patterns. The study thus considers the economic and energy conditions under which a 2030 CO_2 emissions peak is possible. To interpret the study's results, it is therefore important to appreciate the relationship between economic growth, the energy intensity of growth, and the emissions intensity of energy (see Box 2, above).

The study modelled three scenarios ('high', 'middle' and 'low') for China's future GDP growth (see Table AI.1, below).

Table A1.1: Three Scenarios for China's economic growth (% Change in GDP)

Period	Low Growth Scenario (%)	Middle Growth Scenario (%)	High Growth Scenario (%)
2010–2020	6.11	7.31	7.87
2020–2030	3.28	4.77	6.02
2030–2050	2.33	3.15	4.60
2010–2050 ave.	3.51	4.60	5.78

Source: GCEC (2014b)

The results of these GDP growth scenarios were then put into the study's energy sector model to analyse energy consumption and CO_2 emissions. The energy model considers two further scenarios concerning efforts to decarbonise the economy:

- **A Continued Emissions Reduction Scenario** (CERS), which assumes China continues to promote energy conservation and emissions reduction strategies, improve energy efficiency and develop non-fossil fuel energy sources through moderate additional policy interventions beyond what was planned at the time (i.e. somewhat beyond "business as usual").

- **An Accelerated Emissions Reduction Scenario** (AERS), which assumes significant additional policy measures beyond the CERS.

It is important to bear in mind that "accelerated effort" must be interpreted from the perspective of when the study was undertaken, in 2013–2014, and that subsequent policy developments and structural change already goes beyond the accelerated effort scenario.

The study finds that China's ability to peak emissions in 2030 is highly sensitive to China's economic growth rate over the next 15 years. The modelling exercise found that even under the "accelerated" scenario, peak emissions in 2030 would not be possible if Chinese GDP were still growing at more than 5% per year on average over the 2020–2030 period.[99] (It must be remembered, however, that this is a modelling projection contingent on assumptions about the relationship between emissions and economic output, not a necessary truth; it is eminently possible that the Chinese economy could sustain >5% growth rates in 2020–2030 while seeing emissions peak during that decade — see Box 2, above.)

99 Assuming growth of >7% per year on average during 2010–2020.

Under the "middle" economic growth scenario — where the Chinese economy averages 7.31% GDP growth per year between 2010–2020, and 4.77% growth between 2020 and 2030 — the energy model's "accelerated" emissions reduction scenario causes CO_2 emissions to peak in 2030. The "middle" economic growth scenario looks plausible in light of experience over the period 2011–2015 and recent forecasts from the World Bank (2015a, 54) and IMF (2015, 54–55). Accordingly, the study focuses on this middle growth scenario as the central scenario for its energy, CO_2, and air pollution analysis, and this is reflected in the results outlined below.

Table 1 in Chapter 3, above, sets out the study's results from its energy sector modelling exercise, showing results for total energy consumption, energy intensity of GDP, CO_2 emissions from energy (as to which see also Figure A1.1, below), the CO_2 (from energy) intensity of GDP, and the proportion of non-fossil energy in the energy mix — in each case for both the "continued" effort and "accelerated" effort scenarios in 2020 and 2030 (2010 actual data are also shown). We also include below projections of total GHG emissions in China from all sectors, assuming that the 2010 ratio of energy CO_2 emissions to total GHG emissions (1:1.3), as recorded in the CAIT database (WRI, 2014) remains constant throughout the relevant period. China's total GHG emissions, as recorded in CAIT, include emissions from all key greenhouse gases[100] and emissions sources, including energy, industrial processes, agriculture, waste, land-use change and forestry (which for China was a net sink in 2010), and bunker fuels (WRI, 2014). We note, however, that this may somewhat overstate future GHG emissions projections, since it is likely that non-CO_2 emissions (especially CH_4 and N_2O from the agriculture sector, and HFCs and N_2O from industry) will not grow as fast as CO_2.[101]

Under the CERS, the projected results are that: the energy intensity of China's GDP cumulatively falls 45.4% between 2010 and 2030, and China's total energy consumption rises to 6.25 billion tonnes (GT) of coal equivalent by 2030, with the non-fossil share of energy reaching 20% by 2030. The CO_2 emissions intensity of China's economy cumulatively falls 48.9% between 2010 and 2030,[102] at which point CO_2 emissions from energy reach 12.7GTCO_2, and keep rising until their peak in 2040. China's total net GHG emissions in 2030 under this scenario would be around 16.5GT.

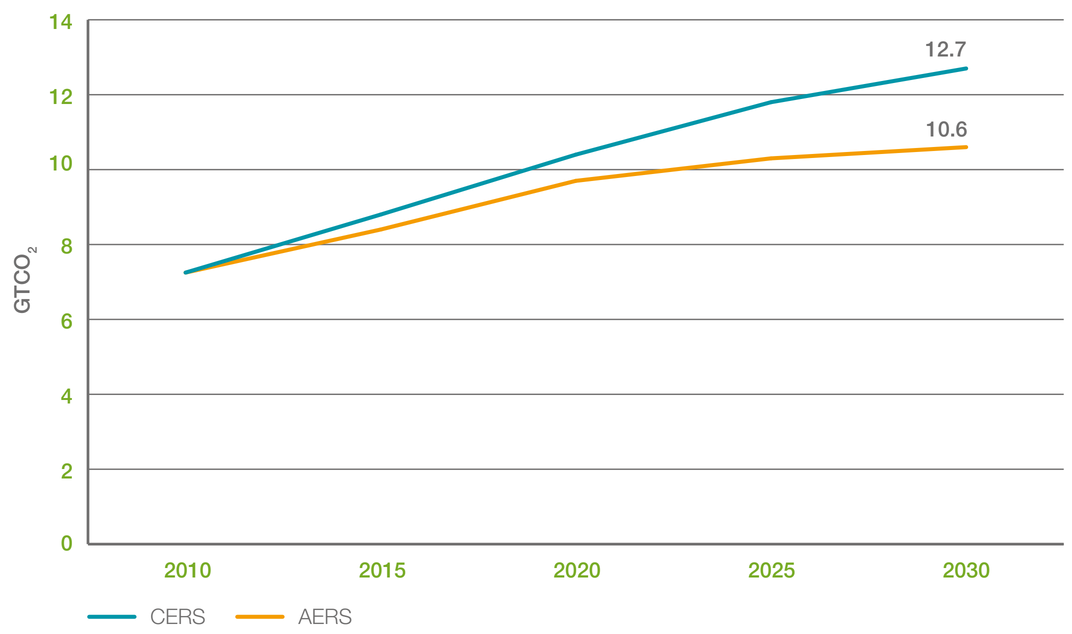
By contrast, under the study's "accelerated" scenario (AERS), China's energy consumption and emissions levels are lower than in the continued effort scenario. Specifically, the energy intensity of China's GDP cumulatively falls 48.4% between 2010 and 2030, and China's total energy consumption rises to 5.9GT of coal equivalent by 2030, with the non-fossil share of energy reaching 23% by 2030. The CO_2 emissions intensity of China's economy falls (or "carbon productivity rises") cumulatively 58.5% between 2010 and 2030, at which point CO_2 emissions from energy reach a peak of 10.6GTCO_2, implying total net GHG emissions in 2030 of 13.8GT.

100 CO_2, CH_4, N_2O and F-gases.

101 We thank Teng Fei bringing this point to our attention.

102 More positively, this can be expressed in terms of the carbon productivity of China's economy rising by these amounts over the relevant period.

Figure A1.1: Projected Chinese CO_2 emissions from energy in the NCE China Study's energy modelling



The study then considered the benefits to China's economy and society in terms of energy security and reduced air pollution under the accelerated effort scenario, and assessed the costs to the economy of this accelerated effort.

Energy security

The study finds that under this (accelerated effort) scenario, China's economy is less dependent on domestic and imported fossil fuels, significantly reducing the vulnerability of its economy to external energy price fluctuations and shocks. Under the CERS, China will be 75% dependent on imported oil in 2030 and coal consumption will go beyond the scientifically assessed domestic production capacity. Under the AERS, by contrast, total energy consumption will be 5% lower than under the CERS by 2030.

Air pollution

With regard to air pollution, the study used an air quality simulation model to model the combined effects of strict "end of pipe" technology (i.e. assuming these are mandated through regulation) and each of the two energy/emissions scenarios discussed above, focusing on the three key production regions of Beijing–Tianjin–Hebei, Pearl River Delta and Yangtze River Delta. Here, "strictness" refers to a combination of the regulated standards and implementation/enforcement of those standards (it is important to remember that countries such as Germany have faced major challenges in implementing end-of-pipe technology, even with a very advanced economy and technology).

The study finds that even with the strictest end of pipe technologies, these regions can only achieve Grade II Air Quality standards if China's energy consumption and energy structure are transformed as per the accelerated effort scenario in which CO_2 emissions also peak by 2030. Without such accelerated efforts consistent with CO_2 emissions peaking in 2030, about 50% of Chinese major cities will fail to meet the air quality standard (even with the most stringent end of pipe technologies). The 2030 emission peaking goal is therefore consistent with China's domestic interests to win the "war on pollution". In this way, the study underscores the importance of the structural transformation away from coal in order to improve air quality standards.

Economic costs of accelerated effort

The study models the economic costs of the accelerated effort scenario using a computable general equilibrium (CGE) model which assumes (for simplicity) that the accelerated policy efforts take the form of a simple carbon tax, the revenue from which is "recycled" (i.e. offset) by equivalent reductions in existing, more distorting taxes (i.e. it is "revenue neutral").[103] The model projects that this scenario would result in very low costs to the economy in terms of conventionally measured GDP (under 1% of GDP to 2030).

It is important to emphasise that this figure, as with all modelling exercises, should be regarded as indicative only and is subject to a number of limitations. Most importantly, the CGE model assumes that the tax is being introduced into a perfectly efficient economy in which there are no distortions or market failures. As such, the economic benefits of the accelerated effort scenario, in the form of enhanced energy security and lower health and environmental costs (discussed above) are not factored into the model. These benefits would likely offset a large portion of the projected GDP costs. The long-term reduction in climate risks associated with such an emissions constraint, and the associated benefits to the economy, are also excluded from the CGE model.

A further limitation of the model, common to CGE models, is that it does not capture the potential for climate policies to induce innovation in green technologies, with knowledge spillovers into other sectors, which are likely to drive higher GDP growth than otherwise (Aghion et al., 2014). It is not only the endogenous, innovation-enhancing effect of the (modelled) tax itself that is left out of the model: greater innovation is likely to be induced by policies directly aimed at supporting green innovation (Aghion et al., 2014), so it is likely to be possible to achieve even greater economic benefits by applying some of the revenue from carbon taxes toward the research and development (and innovation more broadly) of clean technologies than by applying it to efficiency-enhancing tax reform.

On the other hand, the policies adopted to achieve the 2030 emissions peak will inevitably include multiple instruments and initiatives (potentially including a carbon tax, but not exclusively a carbon tax), not all of which are likely to be as economically efficient as a carbon tax. In addition, not all of the revenue from market-based policy instruments may be recycled in an efficiency-enhancing way. Accordingly, the economic costs of the policy changes recommended in the study could turn out higher than the study finds. However, this argument makes a false assumption that market instruments and efficiency-enhancing tax reforms are *necessarily* more efficient than alternative policies and expenditures. In fact, there are circumstances and sectors in which regulation can induce faster innovation (and hence be more efficient) than market instruments — including energy efficiency standards for buildings, appliances and vehicles (Daley and Edis, 2011).

Ultimately, the key point is that, with well-designed policy in place, GDP costs associated with the achievement of the study's 2030 peaking target would likely be modest and — due to difficult-to-model beneficial effects on resource productivity, infrastructure investment, innovation, energy security, and public health — could in fact be net-beneficial to GDP. Of course, these are likely to yield improvements in economic efficiency and human welfare well beyond those captured in GDP figures, for the reasons discussed above and in the NCE Global Report (GCEC, 2014a).

103 On wider tax reform in China, see Ahmad et al. (2013).

Policy measures

The study concludes that China's coal consumption should be capped so that it peaks by around 2020, followed by an absolute decline as soon as possible thereafter. In the study's modelling, oil and gas consumption are likely to continue to expand out to 2030, therefore if total emissions are to peak by that time, coal needs to peak around ten years earlier (but see our discussion of this issue in Chapter 4.4, above).

Additionally, the study advocates the gradual introduction of absolute emissions targets and carbon pricing. It argues that targets should first be introduced for energy-intensive industries that are overcapacity or are located in the relatively developed economies of eastern China, and then gradually expanded to all industries and regions, and ultimately to an economy-wide emissions reduction target. With regard to carbon pricing, the study advocates the introduction of a steadily rising carbon price signal, rising at 7–8% per year before 2030, to direct the investment towards a low carbon green development path.

Appendix II: Electricity generation data

Table A2.1: Electricity generation capacity in China by source — 2014 additions and total capacity at end of 2014

Generation Source	Capacity added in 2014 (GW)	Total generation capacity at end 2014 (GW)
Thermal	47.29	920
— Coal	*35.55*	*830*
— Gas	*8.86*	*55.67*
— Other thermal[104]	*2.88*	*34.33*
Hydroelectricity[105]	21.85	301.83
Nuclear	5.47	19.88
Wind	20.72	95.81
Solar (mostly PV)	10.64	26.52
Total[106]	**105.97**	**1360**

Source: China Electricity Council (2015b) unless otherwise specified.

104 This includes biomass, cogeneration and wastes, calculated here as a residual from coal and gas capacity additions.

105 The figure for total installed hydroelectric capacity in CEC (2015a) is 301.83GW, which is slightly greater than the figure given in CEC (2015b), namely 300GW. We assume the latter figure is rounded down (in both documents, the capacity added is 21.85GW, and earlier data for 2013 show total hydro capacity at the end of 2013 of 280GW), so we have included the slightly larger figure in the table.

106 Total capacity added in 2014 is the aggregate of capacities added from individual sources. Total generation capacity is the aggregate of individual sources rounded to three significant figures, which reflects the CEC (2015b) stated figure of total generation capacity (1.36TW).

Table A2.2: Electricity generation output from thermal sources, 2013–2014				
Generation Source	Generation Output 2013 (TWh)	Generation Output 2014 (TWh)	2013–14 change (TWh)	Percentage change, 2013–14 (%)
Total thermal	4199.4	4170	–29.4	–0.7
Non-coal thermal[107]	185.1	212.87	27.77	15
Coal[108]	4014.3	3957.13	–57.17	–1.4

Source: China Electricity Council (2015b)

Table A2.3: Hydroelectric utilisation rates and capacity			
Year	Hydroelectric Capacity Utilisation (hours/year)	Hydroelectric Capacity Utilisation (%)	Cumulative Total Hydroelectric Capacity at end of year (GW)
2008[9]	3589	41	173
2009[10]	3264	37	197
2010[11]	3429	39	213
2011[12]	3028	35	230
2012[13]	3555	41	249
2013[14]	3318	38	280
2014[15]	3653	42	302
Average	3405	39	

Sources as per footnotes for each year.

107 Total non-coal thermal generation capacity was 90GW in 2014, up 11.74GW compared with 2013 (from Table A2.1, above; CEC, 2015b). Assuming a capacity factor of 27% for non-coal thermal generation in 2013 and 2014 (this is consistent with the IEA's calculation of the non-coal thermal capacity factor for 2012: IEA, 2014a), that implies 212.87TWh of non-coal thermal generation in 2014, up 27.77TWh compared with 2013. (NBS data do not provide a breakdown of thermal generation.)
108 Calculated as a residual.
109 http://www.gov.cn/gzdt/2010-01/06/content_1504129.htm
110 http://www.gov.cn/gzdt/2010-01/06/content_1504129.htm
111 http://www.nea.gov.cn/2011-01/28/c_131054979.htm
112 http://www.nea.gov.cn/2012-01/14/c_131360365.htm
113 http://www.nea.gov.cn/2013-01/14/c_132100340.htm
114 http://www.nea.gov.cn/2014-01/14/c_133043689.htm
115 CEC (2015a).

Appendix III: Illustrative scenario for peak CO_2 emissions from energy in China by 2020

In Chapter 4.4 we concluded that China's greenhouse gas (GHG) emissions are likely to peak by 2025, and could well peak earlier. Below, we present an illustrative scenario in which China's CO_2 emissions from energy peak by 2020, explaining the underlying assumptions to illustrate how this could happen. Table A3.1 sets out an illustrative scenario for changes in China's *energy consumption* between 2014–2020. Table A3.2 shows that such a scenario leads to a peak in *associated CO_2 emissions* from energy by 2020.

In Table A3.1 we assume (for the period 2014–2020):

- *Total primary energy consumption (PEC) increases at a compound annual average rate of 1.8%*. On recent trends, China's energy demand increased 2.2% between 2013 and 2014 (NBS, 2015a), and only 1% in Q1 2015, reflecting structural and policy changes that are likely to continue. The 1.8% energy demand growth we assume would be obtained if China's economy grew at a compound annual rate of 6% between 2014–2020 (reasonable in light of current structural changes and the latest IMF forecasts of growth slowing to 6.8% in 2015 and 6.3% in 2016)[116] and if the energy intensity of GDP fell at 4% per year.[117]

- *The non-fossil share of primary energy consumption increases to 18% by 2020.* This is higher than China's stated goal for 2020, but in our view a more likely projection given our predicted lower growth in overall energy demand and the likely expansion of capacity targets for wind and solar by 2020.

- *Oil consumption grows at a compound annual average rate of 2.5%.* This is the growth rate forecast by the IEA over this period (2014a).[118]

- *Gas consumption grows at a compound annual average rate of 10%*. This would see gas reaching nearly 9% of primary energy consumption (on our assumptions of growth in the latter), which is slightly less than the government's target of 10%.

116 This would yield an average growth rate over 2011–2020 of 6.81% when actual 2011–2013 figures are included (World Bank, 2015a, 54; IMF, 2015, 54), which would correspond to just over halfway between the "low" and "middle" growth scenario in the NCE China Study (see Appendix I, Table A1.1). Compare also Teng and Jotzo (2014), who assumed 7.4% GDP growth between 2014–2020. Given that growth has fallen more quickly than when these studies were undertaken, and given the IMF's recent forecasts for 2015–16, we think the 6% growth rate for the remainder of this decade is plausible (in any case, it is not a prediction per se, since this is just an illustrative scenario to demonstrate that energy CO_2 emissions could well peak by 2020).

117 A 4% fall in energy intensity of GDP is reasonable: energy intensity fell on average 4.25% over 2013–14 (see Chapter 6.1, above); and 4% p.a. energy intensity improvement is commonly assumed by other leading scholars (e.g. Teng and Jotzo, 2014). While the lower growth level we assume here (compare the studies cited in footnote 116, above) would make achieving the energy intensity reductions more difficult, on the other hand, changes in the investment share of GDP and structure of the economy are likely to accelerate over this period, which could help to sustain intensity reductions of ~4% notwithstanding the lower growth.

118 We infer the compound annual growth rate for oil and gas consumption projected by the IEA (2014a) over the period 2012–2020 and assume the same rate applies over the period 2014–2020, using NBS (2015a) data for the energy consumed from each fuel in 2014 as the base. But recall our conclusion that transport emissions are likely to grow slower than projected in the IEA's New Policies Scenario due to expected expansions in policy in the 13th Five-Year Plan, hence 2.5% growth in oil consumption over this period could reasonably be seen as a high estimate.

When these assumptions are applied to the base values for each energy source in 2014, as per NBS (2015a), the result is an annual average reduction in coal use of 1.2% between 2014–2020. This is roughly consistent with our analysis of trends in coal use in industry and electricity, albeit with the assumption that the structural risks of coal consumption growth we identify (coal bases, and strong growth in coal to chemicals and coal to gas industries) do not eventuate and the downward pressures on coal use we identify dominate. This can thus be seen as a defensibly plausible "low coal" scenario. It can be seen from Table A3.2, applying IPCC emissions factors, that CO_2 emissions from all energy sources would be negative in 2020, indicating a peak in emissions by 2020.[119]

Table A3.1: Projected change in fossil fuel energy consumption (MT Standard Coal Equivalent)

Year	Total PEC	Non-fossil	Total fossil	*Oil*	*Gas*	*Coal*
2014	4,260	481	3,779	*731*	*236*	*2,812*
2020	4,727	851	3,876	*847*	*419*	*2,610*
Growth 2014–20	467	370	98	*117*	*182*	*–201*
Growth rate 2014-20	1.8%	10%	0%	*2.5%*	*10%*	*–1.2%*

Note: Values may not sum to totals due to rounding.

Table A3.2: Projected change in CO_2 emissions from fossil fuel energy consumption ($MTCO_2$)

	Oil	Gas	Coal	Total
2014	1,570	388	7,794	9,752
2020	1,821	688	7,236	9,745
Growth 2014-20	251	300	–558	–7

Note: Multiplies results from Table A3.1 by applicable emissions factors (γtCO_2 per tonne of standard coal equivalent, where γ = 2.772 for coal, 2.149 for oil, and 1.644 for gas). Values may not sum to totals due to rounding.

119 Assuming a constant rate of rate of growth (decline, in the case of coal) each year, CO_2 emissions from energy would have already peaked, but in reality coal is likely to fall at an accelerating rate and oil and gas are likely to grow at a decelerating rate, implying that the peak may come closer to 2020.
120 IPCC emissions factors are available from http://www.ipcc-nggip.iges.or.jp/public/2006gl/

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