Centre for Climate Change Economics and Policy

An ESRC Research Centre

Grantham Research Institute on Climate Change and the Environment

China's 'new normal': better growth, better climate

Fergus Green and Nicholas Stern

Policy paper

March 2015

ESRC Centre for Climate Change Economics and Policy

Grantham Research Institute on Climate Change and the Environment

Note: This is the English version of our paper published in mandarin in the Journal of the China Development Forum (CDF) 2015. This version contains some minor amendments from the CDF version and so should be taken to be authoritative. Appendices to this version are available on the websites of the Grantham Research Institute on Climate Change and the Environment and the ESRC Centre for Climate Change Economics and Policy. A longer version of the paper, incorporating the appendices and containing updates to reflect discussions at the China Development Forum, will be published as a policy brief following the Forum.

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

Global Green Growth Institute

The Grantham Foundation for the Protection of the Environment

University of Leeds

LSE The London School of Economics and Political Science

The ESRC Centre for Climate Change Economics and Policy (CCCEP) was established in 2008 to advance public and private action on climate change through rigorous, innovative research. The Centre is hosted jointly by the University of Leeds and the London School of Economics and Political Science. It is funded by the UK Economic and Social Research Council. More information about the ESRC Centre for Climate Change Economics and Policy can be found at: http://www.cccep.ac.uk

The Grantham Research Institute on Climate Change and the Environment was established in 2008 at the London School of Economics and Political Science. The Institute brings together international expertise on economics, as well as finance, geography, the environment, international development and political economy to establish a world-leading centre for policy-relevant research, teaching and training in climate change and the environment. It is funded by the Grantham Foundation for the Protection of the Environment, which also funds the Grantham Institute for Climate Change at Imperial College London. More information about the Grantham Research Institute can be found at: http://www.lse.ac.uk/grantham/

The Authors

Fergus Green is a Policy Analyst and Research Advisor to Professor Stern at the Grantham Research Institute on Climate Change and the Environment and the ESRC Centre for Climate Change Economics and Policy at the London School of Economics and Political Science.

Nicholas Stern is the I.G. Patel Professor of Economics & Government and Chair of the Grantham Research Institute on Climate Change and the Environment at the London School of Economics and Political Science; Chair of the ESRC Centre for Climate Change Economics and Policy; and President of the British Academy.

Notes and acknowledgements

This policy paper is intended to inform decision-makers in the public, private and third sectors. It has been reviewed by at least two external referees before publication. The views expressed in this paper represent those of the authors and do not necessarily represent those of the host institutions or funders.

This policy paper is the English version of our article published in mandarin in the *Journal of the China Development Forum* (CDF) 2015. This paper contains some minor amendments from and so should be taken to be authoritative. A document containing four online appendices to this paper is available from http://www.lse.ac.uk/GranthamInstitute/. A longer version, incorporating the appendices and containing updates to reflect discussions at the China Development Forum, will be published as a Grantham Research Institute Policy Brief in the month after the Forum.

The authors are very grateful to Ehtisham Ahmad, Ross Garnaut, and Karl Hallding for their guidance on and review of the paper. Thanks also to Rodney Boyd, Ben Caldecott, Teng Fei, Sam Geall, Guoyi Han, Lauri Myllyvirta, Felix Preston, Shane Tomlinson, Wang Jianliang, Qi Ye, 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.

Introduction

This paper examines the potential for China's new economic development model — its "new normal" — to usher in an economy that is not only high-income, low-pollution and energy-secure, but also low-carbon. Part 1 sets out the global context of a series of transformations that will play out over the coming two decades. Part 2 explains China's new development model and its recent policies and announcements relating to climate change, and considers their potential implications for China's greenhouse gas (GHG) emissions. Part 3 analyses recent trends in data and policy to consider the prospects for an early peak, and relatively low peaking level, for China's emissions. Part 4 suggests areas of strategic focus and policy reform that could enable China's emissions to fall at an accelerating rate, post-peak.

As we shall show, achieving an early and (relatively) low emissions peak, and then an accelerating rate of fall of emissions thereafter is eminently achievable within China's new development model. It will require a strong focus on compact city planning, fundamental changes in China's energy system, and a concerted focus on clean innovation, all in the context of wider macroeconomic change and fiscal and governance reforms. It requires, in other words, that China's "new normal" imply a dynamic process of structural transformation, in which structural change enables sustainable growth, energy security, a clean environment, and a steep decline in emissions to reinforce one another. It requires, in other words, that China's "new normal" be a truly "new climate economy". And it would bring a very attractive future for the Chinese people.

1. The global context: multiple transformations[1]

We are at a remarkable point in time — an immense structural transformation in the global economy that will play out over the next two decades. We have already seen radical change in the balance of economic activity towards emerging market and developing countries. This shift will continue apace. Global population is expected to reach around 9.5 billion by 2050. And the number of those people living in urban areas is likely to increase around 3 billion on the 3.7 billion or so today. We are in the midst of an information and communication technology revolution that is upending old practices and modes of social interaction. On top of this technological revolution, we are experiencing others in materials and biotechnology.

At the same time, the world faces great challenges over the next two decades. The growth of recent decades, while bringing many benefits, has been uneven. Billions of people remain in poverty, inequality within countries has mostly grown, and the world faces a difficult macroeconomic period ahead, with slow growth in rich countries, continuing financial challenges, and structural adjustment to technical and economic change. The past decades of growth, moreover, have also placed enormous pressures on natural resources and the environment, including the air we breathe, the water we drink, and the land we use. We are already starting to see increasing recognition across the globe of the need to reduce pollution, congestion and waste in urban and natural environments. This recognition will surely grow in the years and decades ahead.

[1] This section draws heavily from Stern (2014; 2015).

Having been fueled by hydrocarbons, the past era of growth has also begun to disrupt the climatic conditions within which our civilizations have developed. The decisions we make over the next two decades — especially in energy systems, cities, and land-use — will largely determine whether or not we have a reasonable chance of avoiding "dangerous" climate change (usually defined as holding the increase in average global surface temperature to less than 2°C above the 19th century levels).

To achieve a "likely" (>66%) chance of holding global temperature increases to within 2°C, global emissions have to be cut from over 50 billion tonnes CO_2e per annum now, to around 35GT in 2030, to well below 20 billion in 2050 — a factor of 2.5 between 2010 and 2050 (IPCC 2014).[2] That means, assuming population moves 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 CO_2e per annum, to around 4 tonnes in 2030, and to around 2 tonnes in 2050.

This is the global strategic context in which decision-making will take place over the next two decades. No government official or business planner can afford to ignore this context. If the changes involved in these multiple structural transformations (aside from climate change) are managed well — radically reducing waste, congestion, pollution, and the degrading or destruction of land and forests, while fueling growth and reducing poverty — the majority of the emissions reductions needed to stay within a 2°C pathway could well be achieved. Achieving the remaining reductions in emissions that are necessary to tackle climate change will require more ambitious policies and investments, but if done wisely these too will bring many attractive economic, social and environmental benefits (GCEC 2014a). If we fail to take such actions then risks of climate change greatly intensify.

2015 is a critical year for global decision-making on many of these issues, with the culmination of numerous important multilateral processes, including the creation and financing of new sustainable development goals and the negotiation of a new international climate agreement in Paris. If these processes are to be successful, decision-makers must understand the relationships between poverty reduction, better growth, climate change mitigation, and climate change adaptation — and the extraordinary window of opportunity we have to pursue them together.

2. The Chinese context: the "new normal" and its implications for China's emissions

a) China's "new normal"

China has recognised this strategic context explicitly, and faster than most. It has been at the forefront of many of the global trends identified above: the shifting global focus of economic activity, rapid economic growth, urbanisation and demographic change, all of which have lifted hundreds of millions out of poverty. But this growth

[2] 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" (>66%) chance (IPCC 2014, Figure SPM.4). 35GT is the midpoint between the IPCC's 10th percentile value and median value in 2030 of those scenarios. 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.

has come with rising inequalities and a grave toll on China's environment and the natural resources on which its population depends.

These social and environmental impacts were particularly acute over the period 2000–2011, in which China's double digit GDP growth was obtained via a heavy-industrial investment-based development strategy involving a very high investment share of expenditure, a high profit share of income, strong dependence on exports to external markets, and exceptionally low proportions of expenditure on domestic consumption and on services (Garnaut et. al. 2014).

Over the last few years, China's development model has begun to change — and it is changing increasingly rapidly. China's economic growth has since 2012 moderated to a "new normal" of around 7% per annum.[3] This moderation is partly the result of the changing structure of China's economy — including as a result of lower returns on capital/fixed-asset investment, high levels of excess capacity (especially in heavy industrial sectors), higher wages, a changing labour force, and natural resource constraints (CCICED 2014). And it is partly due to policies to correct the undesirable economic, social and environmental effects of China's heavy industrial development phase.

China's central government has recognised that sustaining strong growth rates — e.g. in the order of 7% until 2020, and in the 4–6% range from 2020 to 2030 — amid these structural pressures requires concerted structural reforms. It has particularly emphasised reforms to: increase the productivity of capital, natural resources and energy; become a more innovative producer and move up the global value chain; shift the balance of growth toward domestic consumption, particularly of services (private and public); expand the role of the market in setting prices and allocating resources; and reduce inequalities (interpersonal, city–rural, and east–west) in the distribution of income and wealth (CCCPC 2013; Zhang 2014). It has also made it clear that China's "new normal" also entails a transition toward better quality growth that involves much lower pollution, congestion, waste and environmental damage (CCCPC 2013; State Council 2013).

b) Implications for China's greenhouse gas emissions

It can readily be seen that most of the structural shifts in China's new development model involve changes that would also strongly reduce China's GHG emissions; the cumulative mitigation potential associated with the full implementation of this new model could be very large (Garnaut 2014; Green and Stern 2014). Additionally, China has made a number of commitments on GHG emissions specifically. These include a commitment by China to reduce the emissions intensity of economic growth 40–45% below 2005 levels by 2020 and, in November 2014 as part of a joint announcement on climate change with the United States, a commitment to peak its CO_2 emissions around 2030, with the intention of peaking earlier (Xinhua 2014b; Whitehouse 2014). China also announced its commitment to raising the non-fossil fuel share of its primary energy to around 20% by 2030 (Xinhua 2014b) and to around 15% by 2020 (State Council 2014), up from around 10% in 2013.

These are developments of global importance. China's new development model and its specific commitments on climate change, at the very least, imply the avoidance of

[3] According to World Bank (2014) data, 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.

a very high Chinese emissions scenario by 2030, of the kind many had feared during China's heavy industrial development phase.[4] However, the level and peaking year of China's emissions, and their trajectory post-peak (plateau or an accelerating rate of fall), remain uncertain. Within the parameters of China's new development model and climate commitments to date, there are better and worse possibilities.

Some such possibilities, and associated policy and planning options, have been investigated in China and by the New Climate Economy (NCE) project of the Global Commission on the Economy and Climate (GCEC).[5] The headline findings of the Commission's ground-breaking study, *China and the New Climate Economy* (GCEC 2014b) (the NCE China Study) are summarised in Table 1, below, and explained in more detail in Appendix I.[6]

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 tce)	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)[7]	***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.

[4] See, e.g., Shealy and Dorian (2010). 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).
[5] Stern is the Co-Chair of the Commission and Chair of its Economics Advisory Panel.
[6] The appendices are available online from http://www.lse.ac.uk/GranthamInstitute/. 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. 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.
[7] 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). 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 (2015). The NCE energy model is being updated to reflect the recent revisions to China's energy statistics in light of the one in five years economic census done in 2014.

The key implication of the study's "accelerated" scenario is that China's GHG emissions could peak at below 14GTCO_2e in 2030 (with per capita emissions at less than 10 tonnes[8]) while maintaining strong economic growth (averaging around 6% p.a. over the period 2010–2030[9]), and with significant benefits in the form of greater energy security and reduced air pollution. This scenario compares favourably with the Study's "continued effort" scenario, under which China's energy CO_2 emissions alone are projected to reach 12.7GT in 2030, implying total GHG emissions of around 16.5GT, or 11 tonnes per capita.[10]

Nonetheless, even if China's emissions were to peak in 2030 at just below 14GTCO_2e, 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). Recall that a desirable 2030 benchmark for such a trajectory is 35GTCO_2e. 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).[11]

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 EU (the three largest emitters), if all other countries increased their ambition in accordance with the IEA's "450 scenario",[12] their total emissions in 2030[13] would be ~23GTCO_2e. To stay within the 35GT benchmark, that would "leave" a total of 12GT for China, the US, and the EU combined (Boyd, Ward and Stern 2015).[14] Thus, *even if the US and EU reduced emissions to zero in 2030* (which is clearly extremely unlikely),[15] that would "leave" a maximum of 12GT for China.[16] It does look as if the world will be substantially above where it would need to be in 2030 for 2°C.

[8] 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 (Table 3.5 on p 52), China's emissions would be 9.5tCO_2e per capita.
[9] Based on the Study's "medium" economic growth scenario.
[10] 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 (Table 3.5 on p 52).
[11] If we adopt the higher 2030 global benchmark (for a "likely" chance of 2°C) of 42GTCO_2e (the IPCC's median value), 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).
[12] Referring to the emissions reductions necessary to be on a pathway to holding concentrations of GHGs in the atmosphere to 450 parts per million, roughly consistent with a 50-50 chance of holding to 2°C. 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).
[13] Along with emissions from international bunker fuels.
[14] 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.
[15] 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

Since the world is likely to be higher in 2030 than an appropriate 2°C pathway, 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 decelerate 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 target of less than 10GTCO_2e (less than 7 tonnes per capita) 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",[17] 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, as we discuss below.

In this context, it is appropriate to consider, first, 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 a year ago, including in the NCE China Study's modelling, and, second, the structures and technologies China could put in place to achieve an accelerating rate of fall in its GHG emissions, post-peak.

3. Prospects for an early and low peak in China's greenhouse gas emissions[18]

One means of gauging the likely peak of China's emissions is to consider trends in the consumption of fossil fuels. Coal accounts for two-thirds of China's primary energy consumption,[19] and the largest source of China's emissions. In 2014, coal consumption fell 2.9% (and coal imports fell 10.9%), according to official Chinese preliminary statistics (NBS 2015).[20] In light of policy and structural trends affecting consumption of coal in both power generation and industry (Garnaut 2014), we think it is likely that total coal use across the Chinese economy has passed a structural peak and entered a structural decline.[21]

---

below 2005 levels by 2025), the EU is projected to be at 3.2GT in 2030, and the US at 3.9GT (Boyd, Ward and Stern 2015). For comparison, the IEA, in its "450 Scenario", allocates 13.1GT in 2030 to the US-EU-China as follows: EU 2.6GT; US3.3GT; China 7.2GT.

[16] Within a range of 5–19GT, corresponding to a range for 2030 emissions benchmarks of 28–42GT (see footnote 14, above).

[17] Quote by Todd Stern in US Department of State (2009).

[18] A longer version of this section, containing greater analytical detail, is in Appendix II in the accompanying online appendix document available from www.lse.ac.uk/GranthamInstitute/.

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

[20] 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 2015a).

[21] It is possible that coal use in electricity may grow slightly in future if seasonal variation in hydrological conditions causes below-average hydroelectric output and hence requires greater output from coal-fired power generation to meet demand. However, we conclude that,

Estimates of a peak date for China's coal have been moving ever earlier over the last decade. A 2020 peak would have seemed highly implausible 10 years ago. Even 12 months ago, when we argued that China could peak coal by 2020, this was considered a minority view (Green and Stern 2014). That coal may have already peaked is a measure of the extraordinary pace of change in China's economic model, and reflects (i) rapid advances in energy technology and its costs; (ii) the Chinese people's growing realisation of the profound health effects of air pollution; and (iii) the commitment of China's leadership to policies for tackling pollution and climate change.

Furthermore, peak coal consumption is regarded as a leading indicator of peak emissions, at least of CO_2 — the question is, leading *by how long*? This is not an area where precision is possible; assumptions need to be made. The NCE China Study finds a ten-year lag between peak coal and peak CO_2 emissions. If the ten year lag is correct, we would expect a peak in Chinese emissions in 2023 (assuming our conclusion of a structural peak in coal consumption in 2013 proves to be correct).

Yet there are grounds for thinking that the peak in CO_2 emissions will come sooner. We can perhaps expect CO_2 emissions from natural gas to continue rising for another decade as gas grows its share in the energy mix (and overall energy consumption continues to grow). However, coal emissions are roughly twice those from gas and numerous factors are likely to limit China's continued expansion of gas beyond the medium term (5–10 years),[22] meaning gas expansion is unlikely to delay China's CO_2 emissions peak substantially. Nor, we think, is oil consumption growth. The government does not have official targets for oil consumption and the pace of moderation in oil consumption growth is less clear. Garnaut (2014, 13–14) considers that trends in the Chinese transport sector and wider shifts in China's economic structure associated with the new development model hold out reasonable prospects for a peak in emissions by 2020.

Accordingly, on the whole, we consider a ten year lag between coal-peak and CO_2-peak to be too high; it is more likely that a peak in China's CO_2 emissions will occur closer to five years after the peak in coal, and thus (if we are correct about coal) closer to 2020 than to 2025. A 2030 peak in CO_2 emissions now seems highly unlikely. The fact that CO_2 emissions from fossil fuels appear to have fallen in 2014 (Evans 2015; Myllyvirta 2015c) lends weight to this view.

While further analytical work on all sources and sinks of emissions would be needed to have strong confidence in the above conclusions,[23] we share Garnaut's (2014) considered opinion that such further work could well confirm the likelihood of a peak in China's GHG emissions by 2020. It is certainly the case that trends and tendencies in Chinese policy in the new development model would mean that targeting such a peak would be a realistic and prudent objective of official policy.

---

controlling for such cyclical variations, it is likely that coal use in electricity has peaked — hence we say "structurally" peaked (see Appendix II for our full analysis). There are other possible reasons why coal use may rise in future, which we also address in Appendix II.

[22] These limiting factors are discussed in more detail in online Appendix III.

[23] Trends and levels of emissions in China's land-sector and in non-CO_2 emissions are less clear, and we have not analysed these for present purposes.

Were China's emissions to peak around 2020, 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.[24]

4. Accelerating the rate of fall of emissions after the peak[25]

Achieving an accelerated rate of fall of emissions after China's emissions peak will be crucial for the task of reducing global emissions, and hence to China's long-term development interests. Achieving the 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 strong reductions to occur 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 strong declines in post-peak emissions will present a particularly weighty challenge for China as it continues to grow and to urbanise. It will require, among other things, concerted efforts in the areas of cities, the energy system, and innovation, supported by wider fiscal reforms.

a) Cities

The urban form and transport infrastructure of cities are extremely long-lived assets that create very long-term "path-dependencies" with respect to land-use, transportation, resource utilisation and hence GHG emissions (Rode and Floater 2013; MGI 2009). Given the extraordinary urbanisation that will occur in China in the coming 10-15 years,[26] 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 livable, attractive, competitive and energy efficient.[27] 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).[28] The power of such

[24] Precise calculations of China's emissions are not available. Leading databases including WRI (2014) and the IEA's emissions database (IEA 2015) differ in their estimations by around 1GT for emissions in 2010, with the former at the lower end and the latter at the higher end.

[25] A longer version of this section, containing greater analytical detail, is in Appendix III in the online appendix document available from http://www.lse.ac.uk/GranthamInstitute/.

[26] 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 (2015a; 2015b) 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 2014a), 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. The McKinsey Global Institute (2009) projected China's urban population would reach 926 million in 2025.

[27] 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.

[28] 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 2014a; CCCPC 2013).

a model can be illustrated by a comparison between Atlanta and Barcelona, two cities with roughly the same population and economic size: Atlanta's CO_2 emissions from private and public transport are 7.5 tonnes per person; Barcelona's are only 0.7 (GCEC 2014a).

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

b) Transforming energy systems

Another key determinant of China's ability to achieve an accelerating rate of fall of emissions, post-peak, will be the energy efficiency, and energy mix, of China's energy system. Energy efficiency — regarding transport, industry, buildings and appliances — is an extremely important part of the story of China's transformation, and is discussed further in Appendix III.[29] Below, we focus on China's energy mix.

i) 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 therefore valuable for China, not only to replace coal in incremental electricity generation, but also to displace existing coal usage — a crucial policy objective for improving public health and accelerating the rate of fall of China's GHG emissions.[30]

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.[31] Other renewables and nuclear will therefore need to be expanded at an accelerating pace if coal is to be phased out.

Solar and wind power capacity has expanded at astonishing rates in China in recent years,[32] exhibiting strong technical progress and cost reductions, thanks in significant part to the scale of manufacturing and deployment in China (see Stern 2015). These and other renewable technologies have the potential to scale fast enough to displace increasing amounts of existing coal from China's energy mix over the coming decades if supported with the right policy environment, including strong demand–side policies, such as feed-in-tariffs (CCICED 2014).

---

[29] The accompanying online appendix document is available from http://www.lse.ac.uk/GranthamInstitute/. See also Green and Stern (2014, part 3(a)).

[30] Associated issues of phasing out the existing coal fleet, and of "stranded assets" risk, are discussed further below and in Appendix III.

[31] Hydroelectric capacity will be limited beyond the medium term by a scarcity of appropriate sites for large dams. Gas will be limited for reasons of energy security and the need to reduce GHG emissions.

[32] China installed a record 13GW of solar in 2013 alone, a further 10.6GW in 2014, and is targeting a further 15GW, more than half of existing capacity, in 2015 (Stanway 2015).

Recent forecasts of Chinese nuclear capacity in 2030 range from 114–175GW.[33] On these forecasts, China would need to deploy around 100–150GW over the 15 years to 2030.[34] France deployed 42GW in the seven years between 1980 and 1987, and the US also deployed large amounts (30GW+) in two separate 3–4 year periods (Yip 2014).[35] China is scaling up its nuclear capacity from a much larger economy 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.

The biggest challenge China may face in continual rapid expansion of these sources is the management of an increasingly complex energy system (IEA 2014b). 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. These will therefore need to be ongoing priorities for China — and indeed for the world.

ii) Limiting new, and phasing out existing, unabated coal

Given the grave threat that coal poses to all aspects of China's "new climate economy" there are strong reasons for China to limit additional coal-based energy and industrial developments, and to move to phase out existing coal as quickly as possible.

Yet, investment in new coal-fired power generation capacity has continued apace, despite the dramatic drop in electricity output from existing coal capacity. This investment is creating wasteful overcapacity, since much of it is not being used,[36] and is unlikely to be used in future given the direction of policy and structural change in China's new development model.[37] Strictly limiting approvals and construction of new coal-fired power plants — unless these are necessary to replace older and less efficient capacity[38] — is thus an important economic objective, quite aside from being a crucial social and environmental one.

The same presumption against new coal investment is also advisable in less developed regions of China (be it investment for local electricity use or for

[33] 2030 forecasts for Chinese nuclear capacity included in this figure are: IEA (2014a, New Policies Scenario) — 114GW; WNA (2015) — 150GW; Wood McKenzie (2014) — 175GW.
[34] China currently has 19GW of nuclear capacity and is targeting an expansion to 58GW of operational capacity by 2020, and a further 30GW under construction by that time (State Council 2014). China currently has 23 nuclear reactors in operation, 26 under construction, and more about to commence construction (WNA 2015).
[35] The United States 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).
[36] Coal-fired generation capacity growth has outstripped coal-fired electricity generation growth since 2011, and the utilization rate has been falling since then, reaching an extraordinary low of 54% in 2014 (Myllyvirta 2015b).
[37] This continued investment in coal can be explained by perverse incentives for heavy-industrial investment by state-owned enterprises, and associated investment practices, that have persisted from the old model of growth (Myllyvirta 2015b).
[38] Due to existing government efforts to close older and less efficient capacity, Garnaut (2014, 9) assumes that the amount of coal per megawatt hour of coal-fired electricity generated will continue to fall by an average of 1% per annum. Mai and Feng (2013) suggest a rate of fall of 1.5% per annum and China's 12th Five-Year Plan suggests 0.6% per annum.

transmission to eastern cities via ultra-high-voltage transmission lines[39]): it would be unfortunate if China decided to develop these regions along the lines of the old, heavy-industrial model, given the hard lessons that have been learned in the eastern regions.

A second type of new 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 would add greatly to industrial coal consumption and water consumption at the SNG plants, 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 (Yang and Jackson 2013).[40] 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 billion cubic meters at the end of the decade (Liu 2014). This would limit emissions to 67.5MT of CO_2 per year (Liu 2014). In our view, such a moratorium would be much more consistent with the early peaking, and strong decline, of coal and emissions that is envisaged here as a necessary part of the global response to climate change.[41]

The imperative to phase out coal leaves China with a challenge of managing its existing, large fleet of coal-fired power plants. 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 CO_2 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. But only if this proves successful could there be a case for maintaining coal (at least on climate mitigation grounds[42]).

Even if a significant roll-out of CCS were to occur, China will face a significant "stranded asset"[43] challenge with regard to its coal fleet.[44] It will therefore be important for all relevant stakeholders in China to undertake careful analysis and planning, and implement appropriate policies and practices, to achieve an orderly phase out,

---

[39] 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). See Slater (2014) for analysis.
[40] 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).
[41] See Part 2(b), above.
[42] 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).
[43] "Stranded assets" can be defined as "assets that have suffered from unanticipated or premature write-downs, devaluations, or conversion to liabilities" (Caldecott 2015).
[44] 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 degree of asset-stranding.

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 accelerate the rate of fall in its emissions, post-peak, and requires careful and early attention.

c) Clean innovation

Achieving an accelerating rate of fall in China's emissions post-peak will require major efforts in low/zero/negative-carbon energy innovation. This will require concerted Chinese policy and financial support across the full innovation chain in China (Green and Stern 2014). 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 technologies.[45] Moreover, as China aspires to become a leader in zero carbon energy R&D,[46] it will need to cultivate the strategic, institutional, financial, managerial and cultural conditions required for this kind of innovation (Zhi et al. 2013; Cao et al. 2013). At the same, more bottom-up, smaller-scale technology and socially-driven approaches to clean 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 electric bikes and solar hot water heaters being instructive cases in point (Tyfield et al. 2015).

d) Taxing coal

Expanded resource taxes, particularly on coal, would support all aspects of China's structural transition, directly and indirectly.[47] In addition to the normal reasons for taxation for revenue purposes (e.g. VAT, 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; Green and Stern 2014). Taxing coal in this way has a number of attractive features, including lower complexity and administration costs (compared with individual taxes for each component and with emissions trading schemes), since the information needed to tax coal inputs is more easily obtainable by governments than is firm-level data on emissions of particular gases (Ahmad and Wang 2013). As such, it could be implemented more quickly and easier to administer, reducing the likelihood of "government failure".[48] Moreover, the better availability of the relevant information and the upstream imposition of the tax would make it harder to evade (CCICED 2014).

---

[45] This is discussed further in Green and Stern (2014, part 3; Boyd, Green and Stern 2015).

[46] 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.

[47] Coal is currently taxed very lightly in China — the unit tax on coal is set at 8–20 RMB per tonne for coking coal and just 0.3–5 RMB for other types of coal — 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).

[48] This is not to deny that there will be significant political challenges associated with *introducing* such a tax.

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.[49] We have previously illustrated the potential incentive effects the tax could have and the revenue it could raise.[50] China's currently low coal price and the decision to reduce coal mean that now is a good time to implement such a measure. In order 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 those 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.[51] Additionally, the partial application of revenues raised from such a coal tax (and from other environmental taxation) to finance support for clean innovation would be a potent policy combination for not only reducing emissions but also fuelling economic growth (Aghion et al. 2014).[52]

The above reform would be a key part of a wider set of fiscal and pricing reforms — which could also include congestion charging, property taxation and the gradual removal of energy price controls — that would accelerate China's transition to a new climate economy (Ahmad et al. 2013; Ahmad and Wang 2013; CCICED 2014; Green and Stern 2014).

5. Conclusion: global implications of China's "new normal"

China's "new normal" development model, this paper has shown, 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, structure and energy efficiency of China's economic growth, and in the mix of China's energy supply, ushered in increasingly strongly through policy developments in recent years, have already led to a remarkably rapid turnaround in China's GHG emissions. As such, it is now possible to say with a considerable degree of confidence that coal use (generally) and CO_2 emissions from electricity generation have structurally peaked in China. While we can be less confident about trends in gas consumption, and in emissions from transport, industry, agriculture and other sources, our analysis suggests that a peak in China's total emissions is more likely to occur closer to 2020 than to 2030. This suggests that China's commitment to peak emissions "around 2030", though welcome, should be seen by others 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

[49] A price on carbon of US$37/t$CO_2$ is currently suggested by US official calculations (Greenstone et al. 2013). But as Stern (2013) shows, its calculation is likely biased downwards.

[50] See Green and Stern (2014, part 4). 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, 6–7).

[51] 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).

[52] See also Green and Stern (2014, parts 3(d) and 4) and references cited therein.

best efforts to peak before 2030; we are beginning to see the fruits of China's best efforts.

The paper has also argued that a strengthened commitment to an ongoing, dynamic process of structural transformation — especially in cities and energy systems, and through supporting policies such as resource tax reform and support for innovation — will be essential to achieving an accelerating fall in China's air pollution and GHG emissions, post-peak.

While this paper has focused on China's domestic transformation to a new climate economy, that transformation will have important repercussions throughout the world.[53] 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.

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 realized 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 new climate economy.

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 China's emissions are highlighted by commentators and officials in rich countries as a justification for inaction in those countries. Continued strong examples of Chinese emissions reduction actions, clearly communicated to other countries, could quieten such voices and lower the political barriers in rich countries to stronger climate action.

And fourth, China can be an example to countries everywhere in the way it goes about reducing its emissions, combining regulation and direct energy conservation measures, support for low-carbon energy (including extensive investment from state development banks, which helps bring down the cost of capital for financing renewable energy projects), 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 global new climate 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

[53] The international aspects of China's transformation are discussed by the authors in an accompanying paper for the 2015 China Development Forum (Boyd, Green and Stern 2015).

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.

Bibliography[54]

Aghion, P., C. Hepburn, A. Teytelboym and D. Zenghelis. 2014. “Path-Dependency, Innovation and the Economics of Climate Change”. Policy Paper. Centre for Climate Change Economics and Policy, Grantham Research Institute on Climate Change & the Environment, and New Climate Economy. http://static.newclimateeconomy.report/wp-content/uploads/2014/11/Path-dependence-and-econ-of-change.pdf.

Ahmad, Ehtisham, James Rydge and Nicholas Stern. 2013. “Structural Change Drives Tax Reform Drives Structural Change”. Paper for the China Development Forum, March 2013.

Ahmad, Ehtisham and Wang Zhikai. 2013. “PR China: Fiscal Reforms for Sustainable Structural Change” (unpublished monograph).

Bloomberg. 2015. “China Boosts Solar Target for 2015 as It Fights Pollution”. *Bloomberg.* 18 March 2015. http://www.bloomberg.com/news/articles/2015-03-18/china-increases-solar-target-for-2015-as-it-fights-air-pollution.

Boyd, Rodney, Nicholas Stern and Bob Ward. 2015. “Emissions scenarios to 2030”. Policy Paper. March 2015. Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment.

Boyd, Rodney, Fergus Green and Nicholas Stern. 2015. “The Road to Paris and Beyond: International Climate Cooperation and the Role of China”. Policy Paper. Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment.

Caldecott, Ben. “Stranded Assets Programme: Introduction”. Smith School of Enterprise and the Environment, University of Oxford. http://www.smithschool.ox.ac.uk/research-programmes/stranded-assets/.

Caldecott, Ben and Nick Robins. 2015. “China's Financial Markets: The Risks and Opportunities of Stranded Assets”. Briefing Paper. Smith School of Enterprise and the Environment, University of Oxford.

Cao, Cong, Ning Li, Xia Li and Li Liu. 2013. “Reforming China’s S&T System”. Science 341(6145): 460-462.

Central Committee of the Communist Party of China [CCCPC]. 2013. “Decision on Major Issues Concerning Comprehensively Deepening Reforms”. 15 November 2013.

[54] Bibliography also contains references cited in the Appendices.

http://news.xinhuanet.com/politics/2013-11/15/c_118164235.htm. English Version available at: http://english.people.com.cn/90785/8525422.html.

Chen, Haiyan, Beisi Jia and S. S. Y. Lau. 2008. “Sustainable urban form for Chinese compact cities: Challenges of a rapid urbanized economy”. Habitat International 32: 28–40.

Chen, Stephen. 2014. “China plans to be world leader in nuclear power by 2020”. South China Morning Post. 14 September 2014. http://www.scmp.com/news/china/article/1591984/china-plans-be-world-leader-nuclear-power-2020?page=all.

China Council for International Cooperation on Environment and Development [CCICED]. 2015. “Evaluation and Prospects for a Green Transition Process in China”. CCICED Task Force Report. http://www.cciced.net/encciced/event/AGM_1/AGM2014/download/201411/P020141117556813567008.pdf.

China Electricity Council [CEC]. 2015a. “2014 Power Industry Briefing”. 2 February 2015. http://www.cec.org.cn/guihuayutongji/gongxufenxi/dianliyunxingjiankuang/2015-02-02/133565.html [in mandarin].

— 2015b. “China Power Industry Situation and Prospects”. 10 March 2015. http://www.cec.org.cn/yaowenkuaidi/2015-03-10/134972.html [in mandarin].

Cohen, Armond. 2015. “No China coal peak in sight; carbon capture will be necessary to tame emissions in this century”. Clean Air Task Force Blog. 18 February 2015. http://www.catf.us/blogs/ahead/2015/02/18/no-china-coal-peak-in-sight-carbon-capture-will-be-necessary-to-tame-emissions-in-this-century/.

Cohen, Armond and Kexin Liu. 2013. “Peak Coal in China — or Long, High Plateau?” Clean Air Task Force Blog. 7 October 2013. http://www.catf.us/blogs/ahead/2013/10/07/peak-coal-in-china-or-long-high-plateau/.

CPNN. 2015. “In 2014 China’s Total Energy Consumption Grew by only 2.2%; Energy Intensity Fell 4.8%”. *CPNN [China Electric Power News Network]*. 21 January 2015. http://www.cpnn.com.cn/zdzgtt/201501/t20150121_778878.html [in mandarin].

Daley, John and Tristan Edis, 2011. *Learning the hard way: Australia's policies to reduce emissions*. Grattan Institute Report No. 2011-2. April 2011. Melbourne: Grattan Institute. http://grattan.edu.au/wp-content/uploads/2014/05/077_report_energy_learning_the_hard_way.pdf.

Ding Yanjun, Han Weijian, Chai Qinhu, Yang Shuhong, and Shen Wei. 2013. “Coal-based synthetic natural gas (SNG): A solution to China’s energy security and CO2 reduction?” *Energy Policy* 55: 445–453.

Energy Information Administration (US) [EIA]. 2014. *China (Oil)*. http://www.eia.gov/countries/cab.cfm?fips=ch.

— 2013a. *International Energy Outlook 2013*.

— 2013b. *China (Electricity Generation)*. http://www.eia.gov/countries/country-data.cfm?fips=CH#elec.

European Environment Agency [EEA]. 2011. “Air pollution impacts from carbon capture and storage (CCS)”. EEA Technical report No 14/2011. Copenhagen: EEA. http://www.eea.europa.eu/publications/carbon-capture-and-storage.

Evans, Simon. 2015. “Official data confirms Chinese coal use fell in 2014”. Carbon Brief. 25 February 2015. http://www.carbonbrief.org/blog/2015/02/official-data-confirms-chinese-coal-use-fell-in-2014/.

Fankhauser, Sam. 2012. “A practitioner’s guide to a low-carbon economy: lessons from the UK”. Policy Paper. Grantham Research Institute on Climate Change & the Environment. January 2012.

Gao, Fan. 2012. “Will there be a shale gas revolution in China by 2020?” Paper. Oxford Institute for Energy Studies. http://www.oxfordenergy.org/2012/04/will-there-be-a-shale-gas-revolution-in-china-by-2020/.

Garnaut, Ross. 2014. “China’s Role in Global Climate Change Mitigation”. *China and World Economy* 22(5): 2–18.

Garnaut, R., L. Song and F. Cai. 2014. “Reform and China’s Long-Term Growth and Development”. In L. Song, R. Garnaut and F. Cai (Eds.) *Deepening Reform for China’s Long- Term Growth and Development*. Canberra: Australian National University E-Press. 3–26.

Global Carbon Project. 2014. “Global Carbon Budget 2014”. September 2014. http://www.globalcarbonproject.org/carbonbudget/14/files/GCP_budget_2014_v1.0_lowres.pdf.

Global Commission on the Economy and Climate [GCEC]. 2015. *New Climate Economy Technical Note: Emission Reduction Potential*.

— 2014a. *Better Growth Better Climate: The New Climate Economy Report*. Washington, D.C.: World Resources Institute.

— 2014b. *China and the New Climate Economy*. Beijing: Tsinghua University.

Green, Fergus and Nicholas Stern. “An Innovative and Sustainable Growth Path for China: A Critical Decade”. Policy Paper. Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment. May 2014. http://www.lse.ac.uk/GranthamInstitute/publication/an-innovative-and-sustainable-growth-path-for-china-a-critical-decade/.

Gunningham, Neil. 2014. “A Shale Gas Revolution for China?” *Climate Policy* 14(2): 302–320.

Hornby, Lucy, Anjli Raval and Neil Hume. 2015. “China’s oil imports climb above 7m barrels a day for first time”. *Financial Times*. 13 January 2015. http://www.ft.com/cms/s/0/78f88222-9aff-11e4-882d-00144feabdc0.html#axzz3SvaiJuAm.

Institute for Sustainable Development and International Relations (IDDRI) / Sustainable Development Solutions Network (SDSN). 2014. *Pathways to Deep Decarbonization: 2014 Report*. September 2014.

Intergovernmental Panel on Climate Change [IPCC]. 2014. "Summary for Policymakers" in *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, et al. (eds.). Cambridge: Cambridge University Press.

International Energy Agency [IEA]. 2015. *Emissions Database*. IEA/OECD, Paris. Available at: http://data.iea.org/.

— 2014a. *World Energy Outlook 2014*. Paris: OECD/IEA.

— 2014b. *Renewable Energy Market Analysis and Forecasts to 2020: Medium-Term Market Report 2014*. Paris: OECD/IEA.

Jiang Kejun. 2014. "China's CO_2 emission scenario toward 2 degree global target". Presentation to Victoria University conference on "Abrupt change in China's energy path: implications for China, Australia and the global climate". http://www.vu.edu.au/sites/default/files/cses/pdfs/Kejun_2014_China's_CO2_emission_scenario.pdf.

Liu, Coco. 2014. "China plans major slowdown of new coal-to-gas projects in bid to cut emissions". *ClimateWire*. 17 December 2014 http://www.eenews.net/climatewire/stories/1060010694.

Ma, Wayne. 2014. "What China's Electricity Usage Says about Growth". *China Real Time, The Wall Street Journal*. 20 January 2014. http://blogs.wsj.com/chinarealtime/2014/01/20/what-chinas-electricity-usage-says-about-growth/.

Mai, Yinhua and Shanghao, Feng. 2013. "Increasing China's Coal-fired Power Generation efficiency: The Impact on Carbon Intensity and the Broader Chinese Economy to 2020". Paper to State Information Centre and National Development and Reform Commission Workshop, Beijing.

McKinsey Global Institute [MGI]. 2009. "Preparing for China's Urban Billion". McKinsey & Company.

Myllyvirta, Lauri. 2015a. "China's coal consumption fell in 2014". *Energy Desk*. 26 January 2015. http://energydesk.greenpeace.org/2015/01/26/official-chinas-coal-consumption-fell-2014/.

— 2015b. "Comment: New coal power plants in China — a (carbon) bubble waiting to burst". *Energy Desk*. 23 February 2015. http://energydesk.greenpeace.org/2015/02/23/comment-new-coal-power-plants-china-carbon-bubble-waiting-burst/.

— 2015c. "Chinese emissions from fossil fuel use fell in 2014". *Energy Desk*. 26 February 2015. http://energydesk.greenpeace.org/2015/02/26/chinese-emissions-fossil-fuel-use-fell-2014/.

National Bureau of Statistics (China). 2015. *Statistical Communiqué of the People's Republic of China on the 2014 National Economic and Social Development National Bureau of Statistics of China*. http://www.stats.gov.cn/english/PressRelease/201502/t20150228_687439.html.

National Development and Reform Commission [NDRC]. 2013. *China's Policies and Actions for Addressing Climate Change*. Beijing: NDRC.

National Energy Administration [NEA]. 2015. "National Energy Administration release of 2014 electricity consumption data". 16 January 2015. http://www.nea.gov.cn/2015-01/16/c_133923477.htm.

Ottery, Christine. 2014. "China's planned coal-to-gas plants to emit over one billion tons of CO_2". *Energy Desk*. 23 July 2014. http://energydesk.greenpeace.org/2014/07/23/chinas-planned-coal-gas-plants-emit-one-billion-tons-co2/

Parry, I., D. Heine, E. Lis and S. Li. 2014. *Getting Energy Prices Right: From Principle to Practice*. Washington, D.C.: IMF. Summary for Policymakers available at http://www.imf.org/external/np/fad/environ/pdf/c1.pdf.

People's Republic of China. 2011. *12th Five-Year Plan*. Available at http://news.xinhuanet.com/politics/2011-03/16/c_121193916.htm [in mandarin].

Reuters. 2015. "China cuts energy intensity almost 5 per cent in 2014". *Reuters*. 21 January 2015.

— 2014a. "China's steel sector needs restructuring, output is peaking – association". *Reuters*. https://uk.news.yahoo.com/chinas-steel-sector-needs-restructuring-output-peaking-association-055011748--business.html#VRDZ4rO.

— 2014b. "China falling behind on 2020 hydro goals as premier urges new dam building". *Reuters*. 10 March 2014. http://www.reuters.com/article/2014/03/10/china-parliament-hydropower-idUSL3N0M70VN20140310.

Rode, Philipp and Graham Floater, 2013. *Going Green: How cities are leading the next economy*. London: LSE Library Services, London School of Economics and Political Science.

Shealy, Malcolm and James P. Dorian. 2010. "Growing Chinese coal use: Dramatic resource and environmental implications". *Energy Policy* 38: 2116–2122.

Slater, Huw. 2014. "Insights: China's 'War on Pollution' and its impact on climate change mitigation". China Carbon Forum. http://www.chinacarbon.info/wp-content/uploads/2014/11/CCF-Insights_September-2014.pdf.

Stanway, David. "China's solar power capacity rises 60 pct to 28 GW in 2014". *Reuters*. 16 February 2015. http://af.reuters.com/article/commoditiesNews/idAFL4N0VQ1XS20150216.

State Council of the People's Republic of China. 2014. "Energy Development Strategic Action Plan (2014–2020)". http://www.gov.cn/zhengce/content/2014-11/19/content_9222.htm [in mandarin].

— 2013. "Air Pollution Prevention and Control Plan".

Stern, Nicholas. 2015 (forthcoming). *Why are We Waiting? The Logic, Urgency, and Promise of Tackling Climate Change.* London: MIT Press.

— 2014. "Growth, Climate and Collaboration: Towards Agreement in Paris 2015". Lecture at *Sciences Po*, Paris, 6 November 2014.

Stevens, Paul. "The shale technology revolution and the implications for energy in China". Presentation to Energy Research Institute, Beijing, China, 9 September 2014.

Teng Fei and Frank Jotzo. 2014. "Reaping the Economic Benefits of Decarbonization for China". *China and the World Economy* 22(5): 37–54.

Trembath, Alex. 2014. "Is Coal Really 'Peaking' in China?" *The Breakgthrough*. 28 August 2014. http://thebreakthrough.org/index.php/voices/energetics/is-coal-really-peaking-in-china.

Tyfield, David, Adrian Ely and Sam Geall. 2015 (forthcoming). "Low Carbon Innovation in China: From overlooked opportunities and Challenges to transitions in power relations and practices". *Sustainable Development*.

United Nations Environment Program [UNEP]. 2014. *The Emissions Gap Report 2014*. Nairobi: UNEP.

Urban China Initiative [UCI]. 2013. "China Needs More People-Centered Compact Cities". http://www.urbanchinainitiative.org/china-needs-more-people-centered-compact-cities/.

US Department of State. 2009. "Dialogue on U.S.–China Partnership on Clean Energy". Remarks by Hillary Rodham Clinton, Secretary of State, with Special Envoy for Climate Change Todd Stern and President of GE Energy China Jack Wen. Taiyang Gong Power Plant, Beijing, China.21 February 2009. http://www.state.gov/secretary/20092013clinton/rm/2009a/02/119433.htm.

Whitehouse, The (US). 2014. "Fact Sheet: U.S.–China Joint Announcement on Climate Change and Clean Energy Cooperation". Office the Press Secretary. http://www.whitehouse.gov/the-press-office/2014/11/11/fact-sheet-us-china-joint-announcement-climate-change-and-clean-energy-c

Wilson, Robert. 2015. "Peak coal in China? Not so fast". *Carbon Counter Blog*. 27 February 2015. https://carboncounter.wordpress.com/2015/02/27/peak-coal-in-china-not-so-fast/.

Wood MacKenzie. 2014. "China to Fall Short of 2030 Nuclear Power Targets". News Release. 27 April 2014. http://www.woodmac.com/public/media-centre/12058383.

World Bank. 2015a. *World Development Indicators (Urban population (% of total)*. http://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS.

— 2015b. *World Development Indicators (China).* http://data.worldbank.org/country/china.

— 2014. *Global Economic Prospects: Regional Outlooks — East Asia and Pacific (Country Forecasts: China).* http://www.worldbank.org/en/publication/global-economic-prospects/regional-outlooks/eap#5.

World Bank and Development Research Centre of the State Council, People's Republic of China [DRC]. 2013. *China 2030: Building a Modern, Harmonious, and Creative Society*. Washington, D.C.: World Bank.

World Nuclear Association [WNA]. 2015. “Nuclear Power in China”. http://www.world-nuclear.org/info/Country-Profiles/Countries-A-F/China--Nuclear-Power/.

World Resources Institute [WRI]. 2014. *Climate Analysis Indicators Tool (CAIT) 2.0*. http://cait2.wri.org/.

Wynn, Gerard. 2015. “China’s carbon emissions: did they really fall in 2014?” *Responding to Climate Change*. 16 February 2015. http://www.rtcc.org/2015/02/16/chinas-carbon-emissions-did-they-really-fall-in-2014/#sthash.eIHJOsEd.dpuf.

Xinhua. 2015a. “News Analysis: China's coal industry freezes over”. *Xinhua English News*. 25 January 2015. http://news.xinhuanet.com/english/indepth/2015-01/25/c_133945656.htm

Xinhua 2015b. “China’s coal production appears to have fallen for the first time since 2000”. *Xinhua*. 23 January 2015. http://news.xinhuanet.com/fortune/2015-01/23/c_1114112421.htm [in mandarin].

— 2014a. “China unveils landmark urbanization plan”. *Xinhua English News*. 16 March 2014. http://news.xinhuanet.com/english/china/2014-03/16/c_133190495.htm.

— 2014b. “China, U.S. announce ambitious climate change goals”. 12 November 2014. http://news.xinhuanet.com/english/china/2014-11/12/c_133785099.htm.

Yang, Chi-Jen and Robert B. Jackson. 2013. “China's synthetic natural gas revolution”. *Nature Climate Change* 3: 852–854.

Yip, Arthur. 2014. “US-China Climate Deal Underscores Need for Substantial Energy Innovation”. The Breakthrough Institute. 9 December 2014. http://thebreakthrough.org/index.php/issues/decarbonization/us-china-climate-deal-underscores-need-for-substantial-energy-innovation.

Zhang Gaoli. 2014. “Comprehensively deepen reforms to promote sustainable and healthy development of the economy and society”. Speech at the 15th China Development Forum. 23 March 2014. http://cpc.people.com.cn/n/2014/0324/c64094-24714056.html [in mandarin].

Zhi, Qiang, Jun Su, Peng Ru, and Laura Diaz Anadon. 2013. “The Evolution of China's National Energy RD&D Programs: The Role of Scientists in Science and Technology Decision Making”. *Energy Policy* 61: 1568–1585.