An innovative and sustainable growth path for China: a critical decade

Fergus Green and Nicholas Stern

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Note

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Executive Summary

- The actions China takes in the next decade will be critical for the future of China and the world. Whether China moves onto an innovative, sustainable and low-carbon growth path this decade will more or less determine both (i) China's longer-term economic prospects in a natural resource-constrained world that places a premium on capital efficiency, technological innovation, knowledge and services, and in which labour and capital are highly mobile, and (ii) the world's prospects of cutting greenhouse gas (GHG) emissions sufficiently to manage the grave risks of climate change.
- The decisions China makes in the next two years, as it develops its 13th Five Year Plan (2016–2020), will have a powerful influence on the actions it takes in the next decade. The next two years, culminating in the United Nations climate conference in Paris in late 2015, is also the period in which countries are likely to conclude crucial global discussions on climate change.
- China's ambitions for more sustainable growth, its urbanisation plans, and its strategic emerging industry policy suggest the potential for a powerful vision: over a billion people living and working in appealing cities, in which services, high-technology industries, and innovation are the engines of growth and prosperity.
- Creating and achieving this vision, and maintaining strong economic growth with a falling savings and investment rate, will require China to increase the productivity of capital. This can be achieved through improvements in efficiency, especially of energy, and through growing the percentage share of services in China's gross domestic product (GDP). These structural shifts could, in turn, be attained through improving China's investment climate, including by making it easier and more predictable for firms to obtain finance. Such improvements would support China's plans to give the market "a decisive role" in resource allocation, reduce the administrative limitations on new firms, diversify capital structures, and reform the role and governance of China's state-owned enterprises.
- China's strategy, which will form the context of and be embodied in its 13th Five Year Plan and related urbanisation plans, could focus on four key areas that could transform China's growth in line with its vision for sustainability and a better quality of life for its people:
    - *Energy Efficiency*: Experience in other countries suggests that China has great scope for reducing the energy intensity of its output in the context of its changing industrial structure. Doing so would yield major savings in China's GHG emissions while improving the productivity of its economy. Three measures that could be especially helpful are: reforming energy markets to ensure prices reflect demand and supply and, increasingly, their full environmental and social costs; regulation, in particular strengthened mandatory performance standards for building energy efficiency; and measures to promote further growth in the energy efficiency services sector.
    - *Cities*: Effective city planning, which promotes dense, compact urban forms, mixed-use development, and accessibility to public transport, is likely to be essential to China's future environmental and economic success. Cities planned according to these fundamental features — especially if combined with green spaces, attractive streetscapes, low pollution levels, and safe walking and cycling infrastructure — will

"lock-in" more efficient land-use and resource-use patterns, and lower pollution, congestion, noise and carbon emissions, for the long-term. In a globalised world, creating these kinds of cities will be vital to achieving China's aspirations to attract the capital and creative talent from around the world necessary to excel in technological innovation and professional services.

- *Coal*: China could intensify its efforts to reduce its reliance on coal, in the form of a plan to peak its coal consumption by 2020 (or earlier), as has been suggested as a possibility in some discussions occurring in China, and phase it out thereafter. This would bring substantial benefits for China's economy: reduced risks of a medium-term energy supply shock; reduced pressure on scarce water supplies; reduced urban air pollution; and reduced risks of climate impacts. Partial solutions that address only one of these problems can exacerbate the other problems. Notably, coal gasification to supply urban centres with synthetic gas for electricity production will increase coal use, GHG emissions and water stress (although successful carbon capture and storage could, at a price, take out the GHG emissions). Only phasing out coal would address all four of these problems. The phase-out goal could be expressed through clear planning targets and implemented via a suite of measures that include regulatory and direct control measures along with a coal tax (discussed further below).
- *Innovation and R&D*: Achieving all of the above would benefit greatly from technological innovation and research and development (R&D) on a large scale. China's current strengths in the final part of the innovation chain — adapting, deploying at scale, and incrementally improving existing low-carbon technologies, as it has done successfully in solar photovoltaics (PV), wind, and high-speed rail — have made great contributions to the global low-carbon innovation effort. But becoming an innovative and sustainable economy requires China to focus its innovation efforts additionally on the first two parts of the innovation chain:
    - *Piloting, commercial demonstration, and early-stage deployment of commercially available technologies (the middle part of the chain), focusing on those that have high potential for cost reductions through learning and scale, for global emissions reduction and for global market growth.* These include: solar PV technologies; concentrating solar power technologies; battery storage; electric vehicles; and the associated network infrastructure (enhanced electricity grids and vehicle charging infrastructure). There is great scope for China to collaborate and coordinate with developed and other emerging countries to bring these crucial low-carbon technologies to maturity — sharing risks, costs and lessons while they are at the higher end of their learning/cost curves and while network and coordination challenges need to be overcome. The size of China's internal market gives it a special — arguably unparalleled — advantage of *scale* that gives it a critical role in this global effort;
    - *Use-inspired basic research, applied research and development of low-carbon technologies (the first part of the innovation chain).* For China to succeed in channelling its growing technical sophistication toward breakthrough

innovations in low-carbon energy over the longer term, it will need to foster the strategic, institutional, financial and cultural conditions required for this kind of innovation. For example, China could establish energy research laboratories that are supported by a long-term (10+ years) research strategy that empowers scientists and research managers with the academic freedom to take risks, fail and learn. These institutions could be embedded within energy innovation clusters that enable researchers to interact with entrepreneurs and venture capitalists, and that provide a legal and financial environment conducive to indigenous, early-stage innovation. This kind of enabling environment will help to ensure China's investments in R&D deliver the immense benefits that early stage low-carbon innovation can yield.

- The medium- to long-term benefits for China's economy and society of pursuing these measures could be very large. They could greatly reduce air and water pollution, increase energy security, reduce GHG emissions, and create healthier, safer, more productive and more appealing cities that power China's growth over the long term. Nonetheless, achieving these benefits will require major structural changes, with some inevitable dislocation, in the short term. Addressing these and other short-term challenges underscores the importance of the energy efficiency measures we discuss, which could bring many short-term economic and social benefits, and of measures to manage the effects of restructuring and dislocation on those affected.
- Achieving these changes will require fiscal and governance reform:
    - At the local level, providing local authorities with the right incentives to ensure sustainable spatial development, invest in sustainable infrastructure, and provide high quality public services to existing and new urban residents is a critical and urgent challenge. Two key fiscal reforms could help China move toward a tax system that provides a more continuous and stable revenue base for its growing cities: a broad-based property tax (which would also lay the foundations for a viable local government bond market to help raise finance for urban infrastructure investment) and fiscal measures to internalise the costs of local urban externalities, particularly those associated with transport (e.g. congestion). Respectively, these measures could raise revenue in the order of 1-1.5% and 0.5% of China's GDP.
    - At the central level, a key fiscal reform is a tax to address the global GHG externality as well as the local environmental, health, and other externalities from coal (and other fossil fuels). In addition to providing powerful incentives for low-carbon development, the revenue from such a tax — potentially in the order of 7-9% of China's GDP — could be used to finance low-carbon innovation and infrastructure, protect poorer people from the impacts of transition, and reduce other taxes. A green investment bank could leverage further private sector capital into low-carbon infrastructure and projects.
    - It is critical that fiscal reforms adhere to sound public finance principles — efficiency, equity and accountability. Adhering to such principles is also pragmatic: a "package" of comprehensive reforms that clearly ties new taxes to investments and services that have direct or indirect benefits to most people, and that form part of a coherent national reformist vision, can help to build coalitions of public support.

- In combination, the measures described above could not only benefit China directly but could stimulate much stronger global action on climate change, with great benefits to China.
    - At present there is ignorance in many places over China's plans and achievements. China can develop its influence by informing the world of its plans as its 13th Five Year Plan is developed. China's contributions are credible given past performance and do not necessarily have to be expressed in formal treaty terms. They could be expressed in terms of a range of outcomes, the upper bound of which could reflect ambitious yet likely achievable goals on emissions, coal consumption and low-carbon technology, although it would be recognised that these could not be guaranteed.
    - Contributions of this nature by China could raise substantially the likelihood of more ambitious mitigation action by developed and other emerging economies. This could trigger a wave of low-carbon innovation and investment. China would be well-positioned to both lead and share in much of the resulting global growth and would benefit immensely from the associated reduction in risks from climate damages.

An Innovative and Sustainable Growth Path for China: A Critical Decade

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1. Introduction

President Xi has remarked that China's current model of economic development is "unbalanced, uncoordinated and unsustainable"[1] and China's leadership has signalled its intention to "accelerate the transformation of the growth model, … make China an *innovative* country" and "promote more *efficient*, *equal* and *sustainable economic development*" (CCCPC 2013). Indeed, achieving this structural transformation will be essential for China's long-term economic prospects in a world that is increasingly natural resource-constrained, efficiency-focused, globalised and concerned with inequality.

China has already shown the world how quickly it can change. In the past 30 years, China's gross domestic product (GDP) grew at around 10% per year on average,[2] hundreds of millions of people were lifted out of poverty, and China's urban population grew by around 250%. This growth has been an extraordinary achievement; but it has been unequal, and has come at great cost to China's environment and the natural resources on which its population depends. Current patterns of urbanisation, structures of governance, and fiscal arrangements are locking in unsustainable physical infrastructure and social relations that will be difficult and costly to alter. In the next decade, it is likely that economic growth will lead to a doubling of China's GDP (associated with a 7% p.a. growth rate), and another 350 million residents will be added to China's cities. It is thus a critical decade; a decade that will effectively determine whether and how the sustainable economic transformation to which China aspires will occur.

If the decade is critical, the next two years are decisive: the decisions China makes as it develops its 13th Five Year Plan (2016–2020) will have a powerful influence on the actions it takes in the next decade. China's new cohort of leaders[3] therefore has an historic opportunity to lay the structural foundations for the next wave of growth and prosperity which will in large measure define its economy, society and sustainability.

It is also a critical decade for the world. To manage the grave risks of climate change effectively, the world must build a zero carbon energy system by the second half of this century. In the context of a growing global economy, we must cut emissions per unit of output by a factor of 7 or 8 over the next four decades. Only a radical transformation — a new energy industrial revolution — would constitute an adequate response to climate change. Due to the "ratchet effect" by which annual flows of

[1] The remarks were made in President Xi's address to the CPC Central Committee at its Third Plenum in November 2013 (see The Economist 2013).
[2] China's average annual GDP Growth (current USD) in each of the three decades from 1980 was 9.75%, 9.99%, and 10.29%, respectively (World Bank 2013).
[3] President Xi Jinping and Premier Li Keqiang began their period in office in March 2013.

greenhouse gas (GHG) emissions add to the existing concentrations in the atmosphere, and due to the lock-in of emissions-intensive capital and infrastructure, the actions taken by the world in the next decade will effectively determine whether this can be achieved. And on this issue, too, the next two years are decisive: at the 17th Conference of the Parties (COP) to the UN Framework Convention on Climate Change (UNFCCC) in Durban in late 2011, countries set a timetable for reaching a new international settlement on climate change in COP21 in Paris in late 2015. This crucial period of global climate discussions will thus conclude around the time that China is likely to be finalising its 13th Five Year Plan.[4]

This paper highlights the interconnections between growth, innovation, efficiency, equity and sustainability in the context of this critical period of China's structural reform. It emphasises that an accelerated transition to a *low-carbon* economy provides a critical link that unites each of these elements, and is thus an attractive potential route to achieving high and sustainable growth. These are the subjects of sections 2-4 of the paper. Section 2 addresses some general macroeconomic considerations applicable to China's sustainable economic transformation, while section 3 sets out some specific actions China could take in regard to energy efficiency, cities, coal, and low-carbon innovation. Section 4 outlines the fiscal and governance reforms that could drive this sustainable transformation. A central message of these sections is that a low-carbon structural transformation along these lines would likely bring many benefits to China *irrespective of what the world does on climate change*.

Section 5 focuses on the international dimension of China's structural transformation. It emphasises not only that the actual reforms China undertakes in the next decade will influence the nature and scale of global climate mitigation, but also that the way China *explains* its emerging objectives and intentions will be of crucial importance in this forthcoming phase of global climate discussions. A key argument of this section is that the more ambitious is China's low-carbon structural transformation, the more other countries — and non-state actors — are likely to increase their own mitigation efforts, and the greater the corresponding benefits that would likely accrue to China, in the form of climate risk reduction and low-carbon innovation and discovery.

Bold and comprehensive reforms now can lead China to the strong, sustainable and equitable economy to which it aspires. In so doing it can make the world safer and more attractive for all.

2. Innovation and Structural Change in China's New Growth Strategy

China has had rapid growth with a high savings/investment rate over the past three decades. In broad macroeconomic terms, the aim of China's structural transformation is to maintain high, if somewhat lower, rates of economic growth (above 7% GDP/year) while reducing its savings/investment rate and growing its consumption share of GDP (12FYP; CCCPC 2013). Drawing on basic macroeconomic principles, this section briefly considers some strategies for achieving this shift.

[4] China's 12th Five Year Plan (2011–2015) was debated by the party leadership at the fifth plenary session of the 17th Central Committee of the Communist Party of China (CPC) in late 2010 and approved by the National People's Congress on 14 March 2011.

Simple theory in the tradition of Roy Harrod (1939) tells us that the growth rate of output is equal to the investment rate (or ratio of investment to output) divided by the incremental capital output ratio or ICOR.[5] In other words, it is the product of the rate of investment and (a measure of) the productivity of investment. Both the intuition and the mathematics of Harrod's result are clear.[6] Thus, one way of expressing the challenge of increasing the share of consumption while maintaining growth is that China should be seeking to increase the efficiency of capital as it reduces the investment rate (Stern 2011).

Four direct means of reducing a country's ICOR include:

(i) structural change towards industries with a lower capital requirement (especially services);
(ii) using capital and producing more efficiently in each industry (especially energy efficiency);
(iii) allocating capital more efficiently across industries (including via the financial sector);
(iv) increasing labour productivity (especially skills, employment and mobility).

Structural change toward industries with a lower capital requirement can be achieved by growing the services sector. The ICOR in China has historically (over the past 20 years, based on net investment) been in the range of 3 to 4, and this has recently climbed to 5, as the growth rate dipped slightly. Developed countries, such as the UK and US, have had a considerably lower ICOR — on average, around 2 to 3 (Stern 2011).[7] As ICORs for the services industries as a whole are around 40% lower than the aggregate ICOR (based on US/UK data), the differences in aggregate ICORs between China and the US/UK can, in part, be explained by the greater share of services in the UK and US economy (around a 75-80% share compared to 45% in China).[8] If China were to reduce its current ICOR from 5 to 4, it could maintain its current (7.8%) GDP growth rate while reducing its net investment rate to around 30%.[9]

As part of this structural shift, China is also planning to grow its high technology and high value-added industries. It is championing seven "strategic emerging industries": energy efficient and environmental technologies; new energy; new-energy vehicles; next generation information technology; biotechnology; advanced equipment manufacture; and new materials. The Government has set targets for the growth of the contribution of these emerging industries to China's GDP: the

[5] The ICOR is $\Delta K/\Delta Y$: where ΔK is investment, or increase in capital, and ΔY is the increase in output, over a given year. The ICOR captures the increment in capital associated with an additional unit of output (Walters 1966).

[6] Essentially the mathematics is $(\Delta Y/Y) = (\Delta K/Y) \div (\Delta K/\Delta Y)$. In other words, the growth rate is equal to the investment rate divided by the ICOR. $\Delta K/\Delta Y$ is clearly a particular version of 'the productivity of investment': it could be influenced by how other inputs and technologies are changing, as well as by changes in the character of capital and how it is used. Strictly speaking, output and investment in this formulation should be "net" concepts. Sometimes these net concepts are not easily calculated and some calculations use gross concepts.

[7] The calculations are based on World Bank (World Development Indicators) data, which attempts to maintain consistency between countries. Estimates of ICORs using country-level data are not necessarily consistent with the estimates quoted. However, exact levels are not the aim here, rather these estimates are provided to illustrate investment and growth strategies that could indicate how China might reduce the aggregate ICOR.

[8] Based on World Bank (World Development Indicators) data, which counts both private and government services. There are problems in consistency of definitions of services across countries.

[9] We have assumed a depreciation rate of 8.5% of capital.

industries are expected to grow 20% each year from a base of around 2% of GDP in 2010 to 8% by 2015 and 15% by 2020 (State Council 2012). If these targets can be achieved, then China's ICOR should further be reduced on the assumption that these modern industries make efficient use of capital and may be "less heavy" than the average of existing activities.

One way to increase the share of services and high-tech industries, and to improve the efficiency of capital generally, is to improve China's *investment climate*. We can think of the investment climate as describing the features of a society that affect the confidence of firms to get things done and to be able to realise a return on their investments. Specifically, this includes the way firms interact with regulatory authorities (administrative, tax, legal etc.), access to and quality of infrastructure, and access to and quality of finance, suitable labour, energy and water, etc.

Improvements in China's investment climate will be a crucial part of China's strategy to expand the role of the market in allocating capital and resources across its economy. Both the CPC Central Committee and Vice-Premier Zhang have emphasised that reforming the relationship between the state and the market will be of central importance in achieving China's sustainable economic transformation: the market is to play "a decisive role" in allocating resources, while the government's role in the economy will gradually move away from direct allocation of resources and toward the provision of public services, "rule of law", macroeconomic and market regulation, correcting market failures and environmental protection (CCCPC 2013; Zhang 2014). It is important to recognise that this is within the context of a strategy for the development of China's economy at the heart of which is a shift away from an unsustainable path towards one which is sustainable.

Consistent with this shift, the government has signalled its intention to reduce the administrative limitations on new firms, diversify capital structures within the economy, and reform the role and governance of China's state-owned enterprises (SOEs). Whereas new entrants previously required approvals to participate in specific activities ("positive lists"), planned reforms would allow them to do whatever is not prohibited ("negative lists"), whereas state activities will be restricted to areas prescribed in positive lists (Zhang 2014). Additionally, the government intends to promote more diversified ownership structures throughout the economy that integrate "state-owned capital, collective capital and non-public capital" (CCCPC 2013).[10] There are also plans to reform the state-owned asset management system and advance modern corporate governance systems for SOEs, including with regard to their financial, management and employment practices (CCCPC 2013). These reforms should help to improve the efficiency with which capital (and resources and labour) is allocated across and within industries (they will also have implications for central government finances, which we touch on in section 4).

Another important way to improve China's investment climate, which will also complement China's market-oriented reforms, is to make it easier and more predictable for firms to obtain finance. The World Bank's Enterprise Surveys suggest that "access to finance" is the greatest challenge to doing

[10] The Third Plenum Decision (CCCPC 2013, [6]) states: "We will allow more state-owned enterprises (SOEs) and enterprises of other types of ownership to develop into mixed enterprises. We will allow non-state-owned capital to hold shares in projects invested by state-owned capital. We will allow mixed enterprises to implement employee stock ownership plans (ESOP) to form communities of capital owners and laborers."

business in China, with more than one in five owners and managers of Chinese firms surveyed in 2012 rating it as their biggest obstacle (World Bank 2014).[11] Notably, the surveys indicated that 90% of fixed assets were financed from firms' internal funds (retained earnings), and only 10% financed by bank loans, supplier credit or equity stock sales. By contrast, the global average is closer to two-thirds and one-third, respectively, suggesting China has great scope to improve the ease with which firms — particularly small-medium enterprises — can gain access to external sources of finance (World Bank 2014).

The above changes could help to improve the efficiency of investment, enhancing the transformative effect of the more specific, sectoral measures to which we now turn.

3. Four Key Areas for Action by China

China's plans for reducing GHG emissions, curbing local air pollution and improving the amenity of urban environments are strong, encompassing energy efficiency, renewable and nuclear energy, electricity supergrids, high-speed rail, electric vehicles, and important actions to improve the sustainability and carbon sink capacity in land-use, forestry and agriculture (see, e.g., 12FYP; NDRC 2013). The scale and pace involved means that China will in many ways be a leader in decarbonising its economy. And yet, on many of these issues, China will need to move faster still if it is to achieve its ambitions for sustainable structural transformation and urbanisation, and if global emissions are to be brought onto a pathway that could give a reasonable chance of avoiding dangerous climate change.[12]

China's current ambitions for more sustainable growth, its urbanisation plans, and its policies towards strategic emerging industries suggest the potential for a powerful vision: over a billion people living and working in appealing cities, in which services, high-technology industries, and innovation are the engines of inclusive growth and prosperity. To realise this vision, China's strategy, which will form the context of and be embodied in its 13th Five Year Plan and related urbanisation plans, is likely to require intensification of actions across four key areas: energy efficiency; cities; coal; and low-carbon innovation. An intensive, low-carbon focus on these areas could transform China's growth, ensuring that it remains high while also being much more efficient, innovation-led, more equitable and environmentally sustainable. In doing so, China could set examples to the world of how government policy and structural reform can lay the foundations for strong growth that is also high quality.

[11] After being presented with a list of 15 business environment obstacles, business owners and top managers in 2,700 firms were asked to choose the biggest obstacle to their business. The data were collected through interview surveys between November 2011 and March 2013 (World Bank 2014).

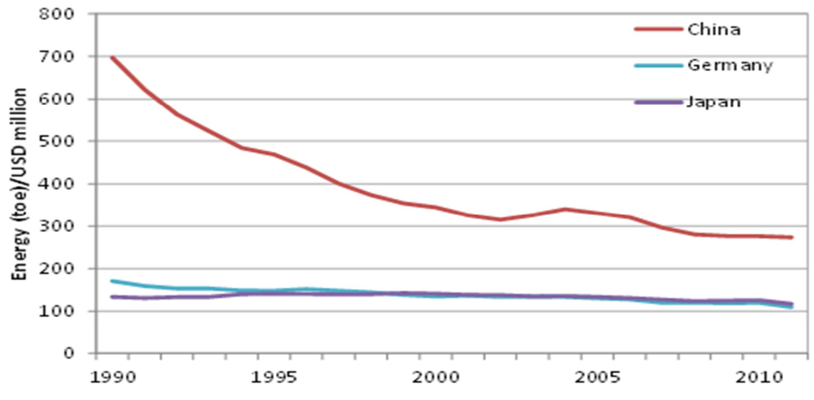
[12] This is usually understood to limiting global average temperature increases to 2°C or less above preindustrial levels, in accordance with the UNFCCC Cancún Decision (2010). "Reasonable" is commonly taken to mean a 50-50 chance but that would still leave non-negligible probabilities of 3°C — temperatures not seen for around 3 million years on this planet.

a) Energy Efficiency

Assuming China continues to grow as strongly as at present (7% p.a. or more), then within the next decade China's economy is likely to have doubled; in other words, China will have the equivalent of one additional economy of similar size to the existing one. If China is to undergo the sustainable economic transformation it desires, and the world is to move onto a 2°C emissions pathway, the "additional" Chinese economy will need to be radically more energy efficient than the existing one. And the efficiency of the existing one will need to be transformed as well.

The energy intensity of China's economy (energy per unit of economic output) has been reduced strongly over the last three decades and, following a spike in the early 2000s, has continued to decline steadily over the last decade thanks largely to measures put in place during this period.[13] However, China appears to be falling behind on its own 12th Five-Year Plan target for a 16% reduction in energy intensity from 2010 levels by the end of 2015.[14] Moreover, the Chinese economy remains considerably more energy intensive than advanced economies, in particular Germany and Japan (Figure 1). While China's industrial structure is currently very different from these countries, the comparison suggests that, as China transforms its economic structure, it has great scope to reduce the energy intensity of its economy.

Figure 1: Energy Intensity of Selected Countries, 1990-2011[15]



Source: WB Development Indicators 2014

Reducing energy intensity, other things being equal, also reduces GHG emissions. In Figure 2 we assume, for illustrative purposes, a gradual reduction in the GHG emissions intensity of China's energy sector (as lower-carbon substitutes for coal are added to the energy mix) and a gradual reduction in China's energy intensity of output,[16] such that the emissions intensity from energy of China's economic output approaches, by about 2040, German/Japanese 2009 levels (blue/green

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[13] 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/.

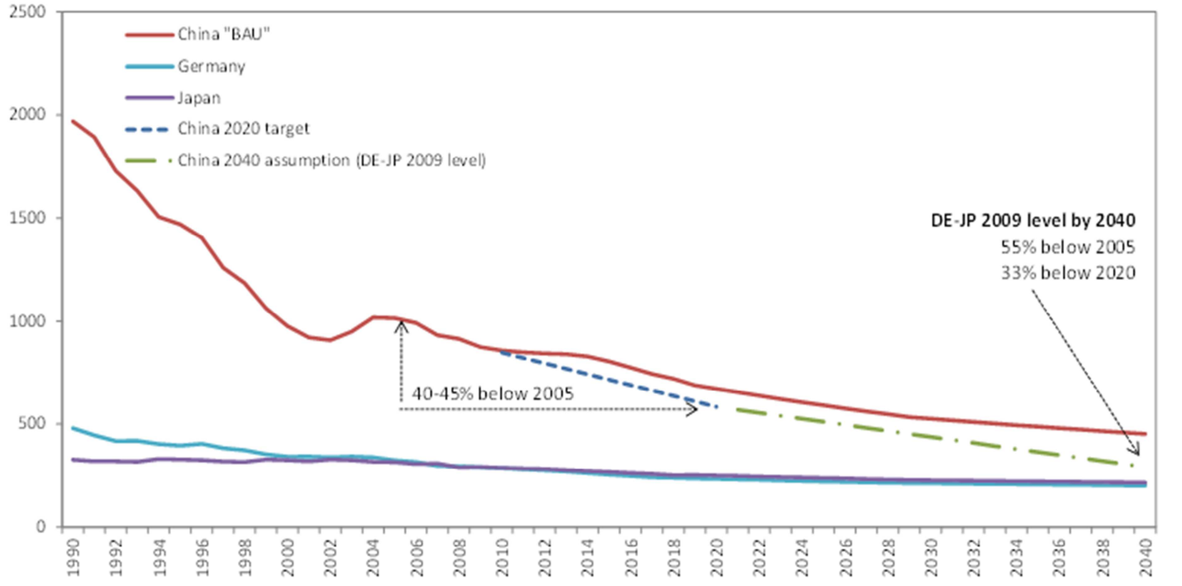
[14] According to Chinese media reports, in the Plan's first two years China achieved only a 5.5% reduction in energy intensity relative to 2010 levels. After a midterm evaluation, the NDRC has reportedly ordered an acceleration in the annual targets from 3.5% to 3.84% for the remaining three years of the Plan (Lelyveld 2013).

[15] GDP measured in USD million at 2005 PPP.

[16] The GHG emissions intensity of economic output, ignoring non-energy sectors, is a function of both the energy intensity of output and the emissions intensity of energy.

dashed lines). We estimate that, under this scenario, China would save roughly 3-5 $GtCO_2e$ per year on average in the period 2020-2040 against a reference scenario (business as usual projection using own calculations — red line continued past 2011).[17]

Figure 2: Emissions from Energy per unit of GDP (tCO_2e per USD million GDP at 2005 PPP)



Sources: WRI, WB, calculations

Large economic gains from energy efficiency improvements in China are also evident. Not only is an improvement in the productivity of energy correlated with improvement in total factor productivity (TFP) and GDP growth rates, but initial econometric analysis in China suggests a *causal* relationship: a 1% increase in energy productivity causes an approximately 1.1% increase in TFP (Ward et al. 2012). We can expect further economic benefits on a large scale to accrue as further measures are put in place to improve China's energy efficiency/productivity.[18]

We briefly highlight three key types of measures that could help China radically improve its energy efficiency over the next decade and beyond. The first is pricing reform. Chinese energy and electricity prices remain subject to a number of distortions that keep prices artificially low (Ahmad and Wang 2013). Demand for energy will fall and energy efficiency will increase if China deregulates retail energy prices (WB/DRC 2013[19]), and will fall further if, through corrective taxation, prices reflect externalities associated with energy consumption, as we discuss in section 4. China's Government is committed to accelerating pricing reform along these lines — including, the rationalization of prices together with the rationalization of ad hoc fees, charges and uncoordinated taxes, and consideration of externality taxation (see, e.g., CCCPC 2013). As we note in section 4, such reforms can be done equitably, through their "packaging" with redistributive and other pro-poor fiscal measures.

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[17] This figure does not factor in any "rebound effect".

[18] A description of the econometric technique used to reach this conclusion is contained in Annex 2 of Ward et al. (2012).

[19] See discussion at pp. 243-244 and references cited there.

The second type of measure is regulation. In particular, the adoption and tightening of mandatory performance standards for energy efficiency in buildings, transport, industry and appliances has the potential to yield large emissions and cost savings.[20] Such standards not only reduce energy use in themselves, but also grow the market demand needed to “pull” the expanding energy, energy efficiency, materials, and technology sectors that are being “pushed” by China’s innovation policies.

Take the example of buildings. China’s building stock in particular is a large and growing consumer of energy and source of emissions. The energy consumption of China’s residential building stock increased 75% in the period 1990-2005 (CPI 2013). With an estimated 40% of China’s building stock to be built between 2010 and 2030 (Liu et al. 2010), that trend is unlikely to be sustainable in relation to the environment and emissions. Encouragingly, China has been among the first developing countries to introduce mandatory Building Energy Efficiency Codes (BEECs), and it has achieved significant success in compliance enforcement (Liu et al. 2010). This provides an important platform for future action: tightening the minimum requirements and strengthening compliance of building codes represents a critical opportunity to save energy and costs for decades to come.[21] Additionally, increasing the integration into buildings of small-scale renewable energy technologies, advanced materials for heating and cooling, “smart” energy demand management technologies, and the battery storage capacity provided by electric vehicles, will provide exciting opportunities for increasingly energy efficient, low-carbon buildings — provided the policy settings give the right incentives. Notably, these technologies span six of China’s seven strategic emerging industry categories, illustrating the powerful potential for China to capitalise on synergies across these burgeoning fields. Moreover, in the context of China’s urbanisation and building construction, these are opportunities that China could pursue at great scale.

Thirdly, it is important for China to support an expanding role for the market to deliver energy efficiency gains. Improving energy efficiency is complex, involving multiple market failures and challenges. Retrofitting *existing* buildings and industrial plant to be more energy efficient, for example, typically involves technical, financial, organisational, behavioural, legal and incentive challenges, all of which make this area considerably more challenging than designing and building highly efficient *new* buildings.[22] Energy Services Companies (ESCOs) can bring the expertise, often lacking within other enterprises, needed to identify, appraise, implement, monitor and evaluate energy efficiency projects. China has already seen rapid growth in its energy services sector, with revenues to ESCOs growing from almost zero in 2000 to US$12 billion in 2010 (The Economist 2014a; WB/DRC 2013), though the sector is more advanced in some parts of the country than others (Draugelis 2012).

[20] There is good evidence of this, for example, from Australia (Daley and Edis 2011).
[21] Of course, improvements in building codes are only part of the process of improving building energy efficiency, which includes building siting, the building envelope, the internal heat network, and the heating system (Draugelis and Li 2012).
[22] In addition to growing the energy efficiency services sector, retrofitting new buildings should become easier as China experiments with different regulatory and incentive schemes in different localities (Draugelis and Li 2012).

The government could further encourage the energy efficiency services sector through, for example, using government contracting to grow the industry, and fostering training and information exchange between government agencies and private ESCOs (Draugelis 2012). Complementary measures to improve energy efficiency lending and investment capabilities in the financial sector, and to develop skills and products that interact more seamlessly than at present with the ESCO sector, will be especially important (Draugelis 2012). In this regard, development-oriented financial institutions can play a powerful role. For example, such institutions could lend to local banks for the purpose of on-supplying credit to firms for energy efficiency projects, and pair the credit with both financial and implementation support to diffuse knowledge and build capacity both in the financial sector and in industry.[23] Importantly, such market-boosting measures will not only help China's energy efficiency efforts indirectly, but will also directly expand the role of the service sector generally and one of China's "new strategic industries" in particular.

b) Cities

The vast majority of China's "additional" economy — and most of its current one — will be located in cities. By 2025, it is expected that China's cities will be home to some 70% of its people,[24] housing an additional 350 million urban residents compared with 2010 and producing 95% of its output (MGI 2009). 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, and resource utilisation (Rode and Floater 2013; MGI 2009). The urban planning decisions, and associated policy and investment choices, China makes today and over the next decade will therefore have long-lasting implications for growth, productivity, GHG emissions, pollution, amenity and social welfare. 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.

Poorly planned cities based on low-density urban sprawl linked by roads — the "Los Angeles" model — lock-in high resource costs, carbon emissions, air pollution, noise and congestion, at great cost to a city's economy (to say nothing of its attractiveness).[25] Many Chinese cities exhibit a worrying trend

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[23] The European Bank for Reconstruction and Development (EBRD) has been in the vanguard of energy efficiency financing and has built up an impressive repository of successful case-studies in a development context in Eastern Europe and central Asia. For example, through its Sustainable Energy Financing Facilities, the Bank extends credit lines to local financial institutions, which on-lend the funds to their clients for energy efficiency and small-scale energy projects, and in addition the Bank mobilises Project Implementation Teams comprising local and international experts who provide support to both the local financial institutions and their clients (EBRD 2014). More information and case studies are available on the EBRD's website: http://www.ebrd.com/pages/sector/energyefficiency/sei/financing.shtml.

[24] China's urban population is projected to increase from 532 million in 2005 to 926 million in 2025 (MGI 2009). Of the 350 million new urban inhabitants that will be added to China's cities over this period, more than 240 million will be rural-urban migrants (MGI 2009). China is already engaged in detailed planning about how to manage this urbanization (Xinhua 2014a).

[25] Road congestion alone is extremely costly. Rode and Floater 2013 conclude that "congestion is often the result of insufficient land-use and transport integration; and the subsequent economic costs are enormous, estimated at 0.75% of GDP in the largely urbanised European Union and in the UK amounting to annual costs of up to £20bn (US$32bn). In many developing world cities, the costs of congestion are even higher: an estimated

toward this model. Recent urban development has caused unsustainable levels of land-take, often consuming valuable farmland or areas providing valuable ecosystem services (MGI 2009; Chen et al. 2008).[26] Moreover, much of China's urban planning has supported a "motorization" trend. The number of motor vehicles in China increased by approximately 20% a year from 1994 to 2008 (Pan 2011). Between 2002 and 2007, per capita incomes in China doubled, but car ownership nearly tripled (Kutzbach 2010). Reversing these trends will be critical if China's next phase of urban and economic growth is to avoid jeopardising China's sustainable growth and low-carbon objectives.[27]

If China's growth model is to be sustainable, at a minimum China's urban form will need to be based on a model of spatially compact, medium/high density cities, tightly linked by mass transit systems. This "Copenhagen / Hong Kong model" of urban planning is widely regarded as a fundamental "support system" for urban green growth,[28] though it is not sufficient to make a city attractive; other elements are 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). To be comprehensively people-centred, cities must also build strong communities and contain other attractive features, including public green spaces, attractive streetscapes, low pollution levels, safe walking and cycling infrastructure, accessibility to employment opportunities, and facilities for social and cultural interaction (see, e.g., Gehl 2014).

With capital and labour being increasingly mobile, both within and between countries, people and industries are better able to relocate to where life is more pleasant. For example, China's success in turning Shanghai into a global financial centre will depend in part on whether it is appealing enough for talented and mobile service professionals to want to live and visit there. More compact, sustainable and resilient cities that are human-centred in the sense described seem much more likely to attract the local and international talent necessary to drive capital investment into services and high-tech industries.

But creating these kinds of cities will require thorough-going fiscal and governance reform so as to provide the right institutional and incentive structures for sustainable planning, service provision and infrastructure development. We discuss these matters in section 4.

3.4% of GDP in Buenos Aires, 2.6% in Mexico City and 3.4% in Dakar" (at p. 48, footnotes omitted — see references there cited).

[26] Arable land per capita in China is less than 50% of the world average and nearly 1.85 million hectares of arable land was converted to urban use over the last decade (Chen et al. 2008). Increasingly, dispersed urban growth consumed green fields and woodlands.

[27] Reducing motorisation in areas already "locked-in" to a road-dependent structure is more difficult, yet major advances are possible through radical increases in the utilisation of vehicles, such as through Bus Rapid Transit systems and other measures (see C40/Arup 2014).

[28] Effective spatial planning, which integrates land-use and transport, and which promotes dense, compact urban forms, mixed-use development, and accessibility to public transport, has been essential to the environmental and economic success of medium-density Copenhagen and ultra high-density Hong Kong (see Rode and Floater 2013 at pp. 48–60 and references cited there).

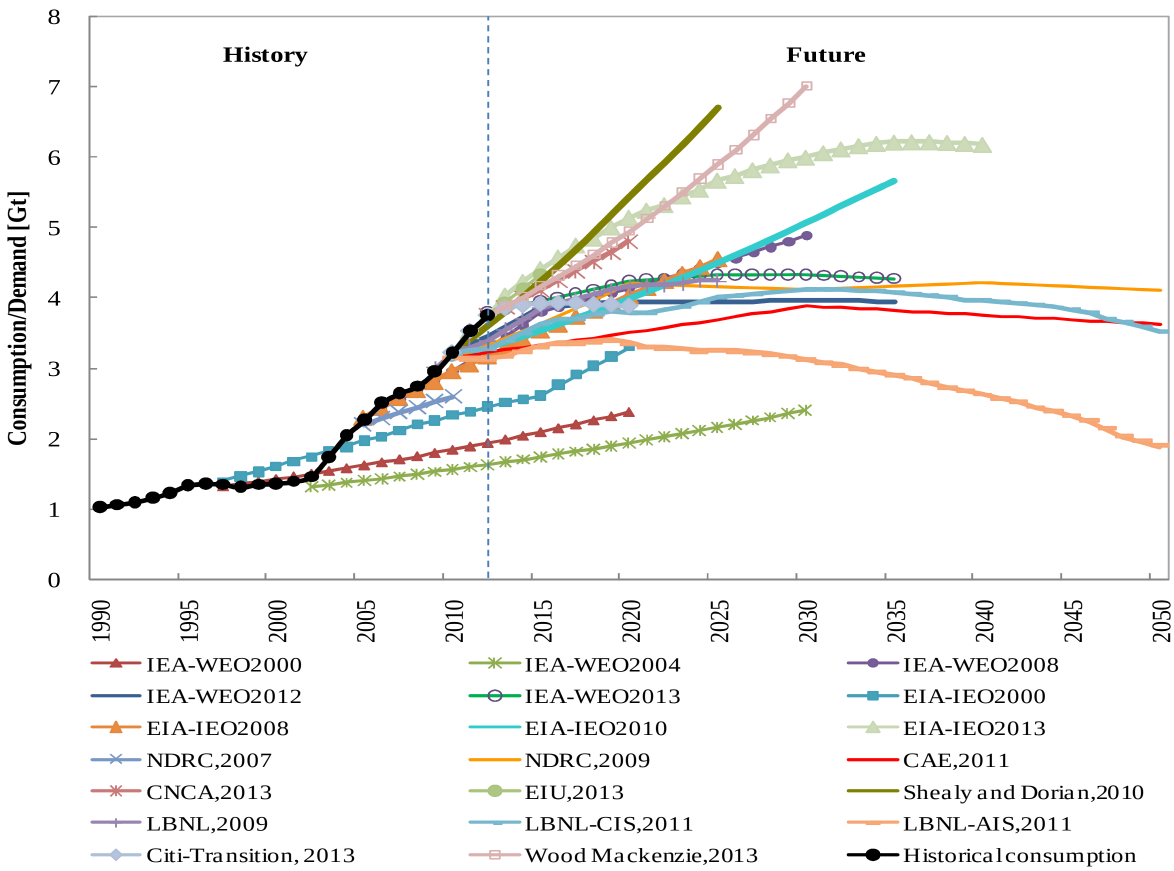
c) Phasing Out Coal

China is currently heavily reliant on coal for its energy and industrial production. China's coal consumption soared over the last decade or so — from roughly 1.5Gt in 2002 to over 3.7Gt in 2012 (BP 2013) — as China's industrial structure underwent a major shift toward energy-intensive, heavy industrial production, and as the country urbanised. While this industrial expansion enabled Chinese GDP to grow strongly over this period, the Government has increasingly recognised the attendant costs and risks, and has taken steps to constrain future growth in coal consumption, raising questions about when China's coal consumption is likely to peak. We explore the issue of peak coal consumption in the first part of this section, and in the second part we consider the benefits to China and the world of China peaking and phasing-out coal as early as possible within the next decade.

China's coal consumption — when will it peak?

The question of when China's coal consumption/demand will peak is of great importance, both to China and the world, and has become a key issue of discussion in Chinese policymaking circles. However, analysing this question is complex, and expert predictions differ widely (see Figure 3).

Figure 3: Chinese coal demand (forecasts from major institutes and international scholars)



Source: Chart constructed by Wang Jianliang, 2014 (not yet published)

On the one hand, there are signs of moderation in China's coal demand, at least with respect to power generation. China's efforts to replace smaller, less efficient coal-fired generation capacity with large, supercritical and ultra-supercritical plants have made a significant contribution to the recent slowing of growth in coal-based thermal electricity generation (Garnaut, R., 2013), saving potentially 100MtCO_2 per year (CPI 2013).[29] The continuation of this "small for large" replacement scheme seems likely to constrain thermal coal consumption in the years immediately ahead (Mai and Shanghao 2013; Garnaut, R., 2013). The acceleration of these and other pollution-control measures in the power generation and heavy industrial sectors — e.g. the provincial level coal consumption reduction targets introduced in three key economic regions, pursuant to China's Airborne Pollution Prevention and Control Action Plan, issued by the State Council in September 2013 (MEP 2013) — may help to bring China's coal consumption to below 65% of total primary energy use within the next year,[30] and may enable China to meet its "cap" on coal consumption of 3.9Gt in 2015.[31] In total, these measures may lead to China's coal consumption peaking within the current decade, with one senior expert predicting recently that the peak will occur in 2020 (Xinhua 2014c), and another as early as 2015.[32] On the other hand, some argue that the government's 3.9Gt coal consumption cap may have already been exceeded, and that China's coal consumption will grow beyond 4GT by 2015.[33] Indeed, many experts see China's coal consumption continuing to rise steeply with economic growth for many years to come (see Figure 3).

Economic growth-based projections of very strong growth in Chinese coal consumption should, however, be viewed with great caution. It can readily be seen that rising economic output need not imply rising coal use. To illustrate, we can see that a peak in coal use (holding coal constant) could be achieved with a doubling of output through a combination of a roughly 30% decline in both coal's share in the energy mix and in the energy intensity of output.[34] Moreover, high demand projections for Chinese coal — e.g. that of Shealy and Dorian (2010), depicted in Figure 3 — imply, on reasonable assumptions about Chinese coal production constraints, a very large increase in Chinese coal imports,

[29] 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).

[30] Coal's share in China's energy consumption was 68.4% of the total in 2011 (NBSC 2012). The National Energy Administration projects that total energy consumption will rise 3.2% in 2014 to 3.88Gt of 'coal equivalent', while coal consumption will rise only 1.6% to 3.8Gt of coal (Platts 2014). China's standard 'coal equivalent' measure assumes coal has a calorific value of 7000kcal/t. In reality Chinese thermal coal has a much lower calorific value, about 5000-5500kcal/t, meaning it takes more than a tonne of coal to generate the energy of one standard coal equivalent.

[31] Dr Jiang Kejun, director of the Energy Research Institute under the NDRC, after presenting a new set of energy scenarios to the State Council, was quoted as saying that "coal consumption will peak below 4 billion tonnes" (Garnaut, J, 2013).

[32] At least one Chinese expert, Professor Pan Jiahua of the Chinese Academy of Social Sciences, has predicted that coal consumption would peak (at less than 4.2Gt) as early as 2015 (see Garnaut, J., 2013).

[33] See, for example, the China Electricity Council's forecasts, cited in China Daily (2012), and sources quoted in Manning (2013).

[34] Coal/output = (coal/energy)x(energy/output). If output doubles, total coal use can stay constant if coal/output halves: and thus, the latter could be achieved by two factors of approximately 0.7 on the right-hand side of the equation.

with attendant risks to Chinese energy security (Wang, Feng & Tverberg 2013).[35] Because of these and other risks associated with coal consumption growth discussed below, China's leadership is now taking the issue of coal consumption extremely seriously at the highest levels, generating an increasingly shared sense that demand must peak at some point within the next decade.

For these reasons, we suggest that China's coal consumption could peak within the next decade. This would be both feasible and, for the reasons discussed below, desirable for China and the world.

The case for an early peak and orderly phase-out of Chinese coal consumption

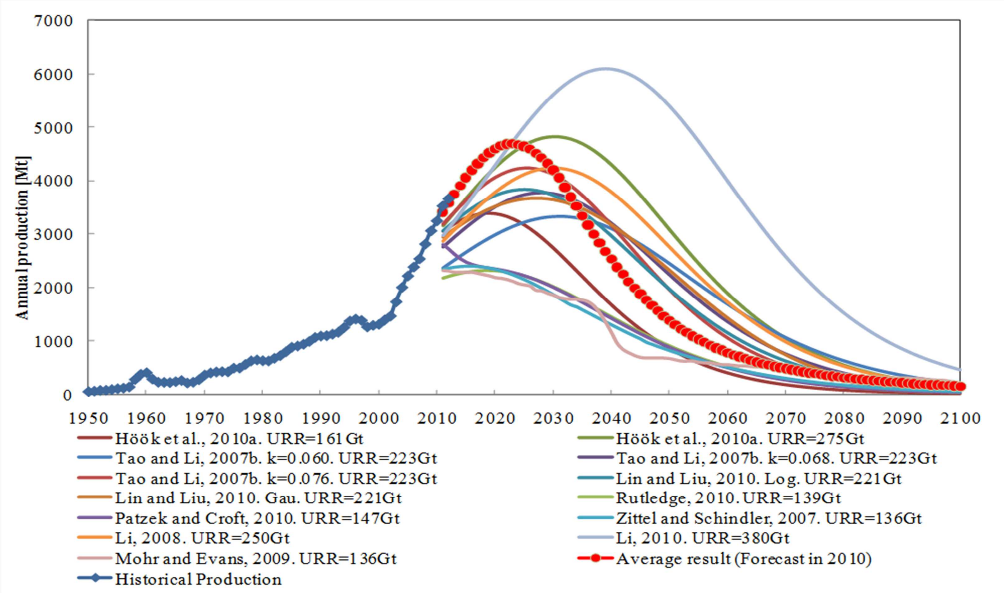
Whatever the expert forecasts may be, intensification of China's efforts to reduce coal, in the form of a plan to peak coal consumption at the early end of China's expert forecasts — i.e. by 2020 or earlier — and to phase it out thereafter would bring major benefits to China in the short, medium and longer term.

First, Chinese domestic coal production, once a pillar of China's energy security, could increasingly become a problem. The rapid expansion of Chinese coal consumption since around 2003 has had two important effects on energy security. It has stimulated an expansion of China's domestic coal production, accelerating the onset of China's future coal production peak — currently projected to occur in around 2020–25 (average of projections from various modelling studies: see Figure 4). Additionally, it has turned China from being a net coal exporter to a net coal importer — and an increasingly large one, with China importing roughly 300Mt of coal in 2012, or about one quarter of world coal exports.[36] If China's coal demand continues to grow at or around rates experienced over the last decade, and Chinese domestic production does indeed peak at around 4Gt in the early 2020s or before, then China would become increasingly reliant on coal imports, and increasingly exposed to international coal price rises — which, owing to China's size in the coal market, could become acute as China's domestic production peaks — and to coal price volatility (Tao and Li 2007; Lin and Liu 2010; Mohr 2010; Wang, Feng & Tverberg 2013). Such exposure could prove costly and disruptive to China, stimulating the need for a rapid substitution away from coal. Decelerating the growth in China's coal demand and peaking demand by around 2020 (or earlier) would, in contrast, mitigate these looming supply pressures and enable China to make a more orderly transition away from coal into substitute energy sources and industrial inputs.

[35] Shealy and Dorian (2010) project that China will consume a huge 6Gt of coal by 2025. However, very few experts see China's domestic coal production peaking at much more than 4Gt (see Figure 4). Wang, Feng & Tverberg 2013 argue that 2Gt supply from imports does not seem feasible: it would imply a more than six-fold increase in China's coal imports, and a near-doubling in the volume of globally traded coal, over the next ten years.

[36] China import data from NBSC (2013a; 2013b). World export data from the US Energy Information Administration (EIA 2014b).

Figure 4: Chinese coal production (forecasts from major institutes and international scholars)



Source: Wang, Feng, Davidsson and Höök 2013

Second, coal contributes greatly to China's water availability problems. The coal industry (mining, processing and power generation) was responsible for 15-20% of China's water consumption in 2010 (BNEF 2013; Schneider 2011). Moreover, China's existing and planned coal production and thermal generation capacity is concentrated in China's most water-stressed regions. Around 85% of China's coal reserves, and 60% of its thermal generating capacity, lie in the North of China, which has less than a quarter of the country's water resources (BNEF 2013; Tan 2013). More than half of the new coal-fired power plants China is planning to build, as at July 2012, would be built in areas of high or extremely high water stress, in the country's north-east (Luo et al. 2013). If China's coal production and consumption continue to grow in these areas, the pressure on water supplies will intensify: 60% of new coal-fired generation capacity is, as at July 2012, proposed to be concentrated in six provinces that account for only 5% of China's total water resources, and in which competition for water between domestic, agricultural, and industrial users is already high (Luo et al. 2013). Meanwhile, water availability is declining. The overall supply of water available in China's rivers, lakes, and aquifers has fallen 13% since 2000 (Schneider 2011), and this trend could worsen as a result of climate change (IPCC 2014).

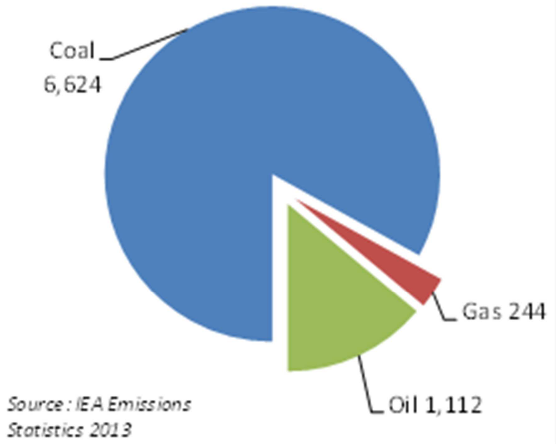
Third, China's increasing coal consumption for electricity and industrial production contributes to the worsening of local air pollution in China's cities, affecting public health (which in turn reduces productivity and raises healthcare costs) and greatly diminishing the amenity of China's urban environment. Measured purely in terms of economic output, China's air pollution is estimated to cost 6.5% of China's GDP (WB/DRC 2013),[37] and coal is the dominant contributor to China's air pollution (WB/SEPA 2007). Phasing out coal would therefore dramatically reduce the health and

[37] An earlier study (WB/SEPA 2007) put the health impacts alone at 3.8% of GDP.

environmental costs of air pollution and help to cultivate the attractive, people-centred cities that will drive China's sustainable economic transformation.

Fourth, China's coal use is a major source of global GHG emissions and therefore increases the risks associated with climate change — risks to which China will be increasingly exposed. In 2011, coal was responsible for more than 80% of China's 8Gt of CO_2 emissions from fossil fuel combustion (Figure 5),[38] which were in turn around a quarter of the *world's* fossil fuel combustion CO_2 emissions (IEA 2013a). In other words, around one fifth of the world's CO_2 emissions from fossil fuel combustion came from Chinese coal.

Figure 5: China CO_2 emissions from fossil fuel combustion by source in 2011 (Total: 8 $GtCO_2$)

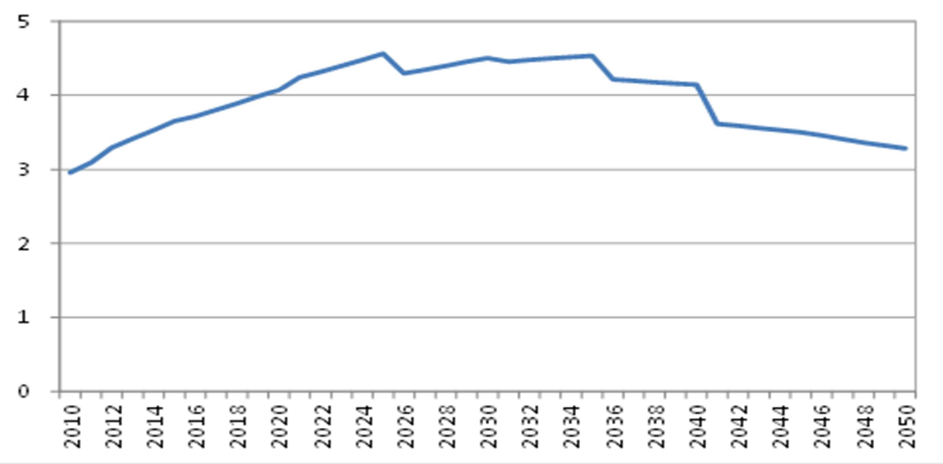


If Chinese coal consumption continues to grow, as most experts project, until sometime between 2025 and 2035, and declines only slowly thereafter (Figure 6), total Chinese emissions would seem likely to exceed $15GtCO_2e$ by 2030, making it almost impossible for the world to move onto an emissions reduction pathway that gives even a 50-50 probability of staying below 2°C.[39] Of course, developed countries are disproportionately responsible for the historical concentrations of emissions in the atmosphere, but the reality is that crossing this threshold would dramatically increase the risks of climate impacts to which China would be exposed — impacts that could reverse much of the growth and development that China has achieved over the preceding decades (IPCC 2014; WB/PIK/CA 2012; Stern 2012).

[38] By comparison, global coal use contributed 43% of the world's $30.3GtCO_2$ emissions from fossil fuel combustion in the same year (IEA 2012a). According to Oliver et al. (2013) coal accounted for roughly three quarters of China's 10Gt of CO_2 emissions from fossil fuel combustion in 2012. China's total CO_2 emissions from fossil fuel use and cement production were over 10Gt in 2012, around 29% of the world total (34.5Gt) (Oliver et al. 2013).

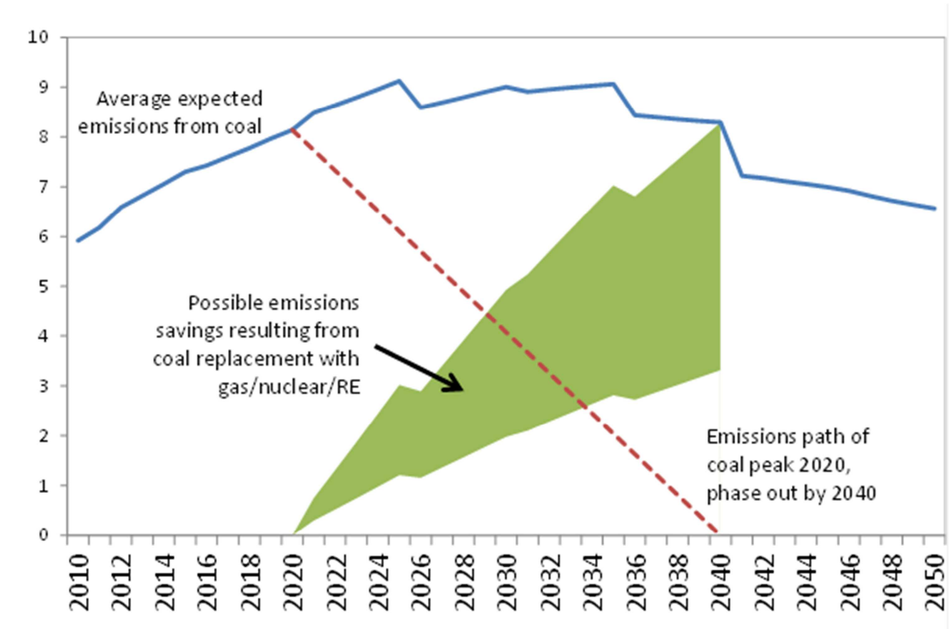
[39] The available 2030 global budget for a 50-50 chance of holding to 2°C is around $32\text{-}33GtCO_2e$ (Bowen and Ranger 2009). As explained by Stern (2012), if China is at $15GtCO_2e$, that would "leave" around 15-16Gt for the remaining 7 billion people projected to be on the planet in 2030, or around just over 2 tonnes per capita (excluding China, world emissions per capita in 2012 were a little over 7 tonnes). But the much more likely outcome is that the global budget would be exceeded and the world would move towards still more dangerous territory (Stern 2012).

Figure 6: Chinese coal consumption (average of forecasts from major institutes and international scholars)



Note: The vertical axis shows Gt of coal
Source: Constructed from data supplied by Wang Jianliang

Figure 7: CO_2 emissions from average coal demand forecast compared with 2020-2040 phase-out scenario



Note: In this figure, the vertical axis is $GtCO_2$, obtained by doubling the coal data from Figure 6, above (which were expressed in Gt coal)
Source: Own calculations based on data provided by Wang Jianliang

A phase-out of China's coal, by contrast, would likely greatly reduce China's GHG emissions, itself reducing China's exposure to climate risks and, as we explain in section 5, potentially catalysing climate change mitigation responses by other countries that reduce the risks of climate change further still. As illustrated in Figure 7, if China were to peak its coal consumption in, say, 2020, and phase it out by 2040 (red dashed line), it would save, on a rough calculation, 4-5GtCO_2 emissions per year from coal relative to the emissions implied in the average of expert forecasts of China's coal demand growth[40] (blue line). Assuming, crudely, that *net* emissions savings are 60% of this reduction, due to resulting replacement of coal use by a combination of gas, nuclear and renewable energy (illustrative assumptions only), China would save 2-3GtCO_2 emissions per year between 2020 and 2040 (green area in Figure 7).[41]

A number of "partial" solutions, intended to remedy only one of these four problems, may have the undesirable consequence of exacerbating the others. Notably, China has (as at 2013) approved the construction of 9 large-scale plants to convert coal to synthetic natural gas (SNG), which can be piped to the major cities on China's east coast and used in gas-fired power plants to produce electricity, displacing air-polluting coal-fired power stations with lower-polluting gas (Yang and Jackson 2013). But the process of converting coal to SNG is extremely energy, water and GHG intensive. 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).

Reducing coal combustion emissions through the application of carbon capture and storage (CCS) technology could be a valuable medium-term opportunity at appropriate prices for GHG emissions. But commercial viability at scale at say US$50 per tonne of CO_2 is some way off. So too, is a national or global price of CO_2 at that level, even though any reasonable estimate of the social cost of carbon would, in our view, be at least at that level and rising. Moreover, there is an "energy penalty" of between 10-25% depending on the type of capture technology applied (EEA 2011). China's scale means that it could play a globally significant role in investigating various CCS technologies. But only if these investigations are successful could there be a case for maintaining coal. The issues of pressure on water supplies (to the extent the coal was being produced domestically) and exposure to international coal price fluctuations (to the extent the coal was being imported) would still arise.[42]

Only phasing out coal could address *all four* of the above-mentioned problems associated with China's coal use.[43] A coal phase-out could be expressed as a planning target and implemented

[40] The average of expert forecasts of coal demand is the above Figure 6, which draws on analysis by Wang Jianliang. We assume 2tCO_2 is emitted from each tonne of coal.

[41] We can assume the phase out of coal use would not directly change energy demand. Rather, the energy that would otherwise have been derived from coal could be replaced with sources that have a lower carbon content — gas (at least in the shorter term), nuclear, hydro and non-hydro renewable energy. Assuming gas produces approximately half the combustion emissions of coal, and nuclear and renewable sources produce zero emissions, we assume approximately 60% of emissions from coal are saved. For simplicity, we ignore upstream emissions from the production of these energy sources, and the indirect effects of energy substitution.

[42] Stern is a member of the Board of the Global Carbon Capture and Storage Institute.

[43] Of course, the impacts of substitute technologies would also need to be considered. However, assumed substitute technologies (renewable energy, large hydro, gas and nuclear) are likely to have significantly lower impacts compared with coal — in some cases considerably so — across all issues considered, with the possible exception of water, depending on the substitute technology in question. Large water supplies are also needed

through a combination of taxation, regulation and investment in alternatives (and complemented by energy efficiency and other demand management measures). Inevitably, China's policy mix for addressing coal will continue to involve regulatory and direct control mechanisms. While less efficient than well-designed market mechanisms, more direct measures have the advantage of being clear and certain, which reduces costs. We consider in section 5 the important role that a coal tax on carbon and environmental/health externalities from coal could play, and the revenue it could raise to finance low-carbon infrastructure and innovation, with a view to rapidly scaling up low-carbon substitute technologies to replace the phased-out coal capacity.

d) Innovation and R&D

Achieving all of the possibilities we have discussed in this section — radically improving energy efficiency, building compact, attractive, low-carbon cities, and replacing coal use with low-carbon energy — will benefit greatly from technological innovation[44] on a large scale. Innovation is, indeed, a growing priority for China. China's 12th Five Year Plan set a target for research and development (R&D) spending to rise to 2.2% of GDP by 2015, and innovation (particularly low-carbon innovation) is central to China's plans for developing its strategic emerging industries (State Council 2012). This prioritisation was underscored in the recent decision of the CPC Central Committee at its Third Plenum, which advocated a comprehensive "national innovation system" for science and technology (CCCPC 2013). We first examine low-carbon innovation from a broad perspective and then briefly discuss two examples.[45]

Numerous market failures contribute to underinvestment in innovation.[46] The problems associated with underinvestment can become more acute as technologies proceed into development, demonstration and early scale commercial deployment, just as the need for capital increases — the so-called "valley of death" (see Figure 8). Research on non-energy sector innovation (e.g. Henderson and Newell 2011) suggests three factors common to successful technology transitions: well-funded, carefully managed R&D programmes; rapid demand growth (which may require collaboration and/or policy); and, at the appropriate point on the innovation chain, strong competition among firms.

The economic incentives for investment in *low-carbon* innovation are further undermined by the mispricing of many existing goods and services central to climate change (especially the under-pricing of GHG emissions),[47] and by the particularly high capital requirements associated with low-carbon

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for nuclear, hydro, hydraulic fracturing for gas, and concentrating solar power, thus careful management of the energy-water trade-offs implied in different coal substitute technologies will be critical.

[44] By technological innovation we mean the full chain of activities, from basic research through to commercial deployment, required to create and diffuse technologies so that they become commercially mature (price competitive at scale without policy support).

[45] Though these should certainly not be the only focus of China's low-carbon innovation efforts, since many other areas of innovation activity will complement the low-carbon transformation we have outlined, including advanced materials (buildings, energy), ICT (smart technologies), and other energy efficient technologies.

[46] These include: positive externalities; public goods aspects of knowledge/technology; imperfections in capital markets and risk-sharing; network infrastructure; and coordination problems.

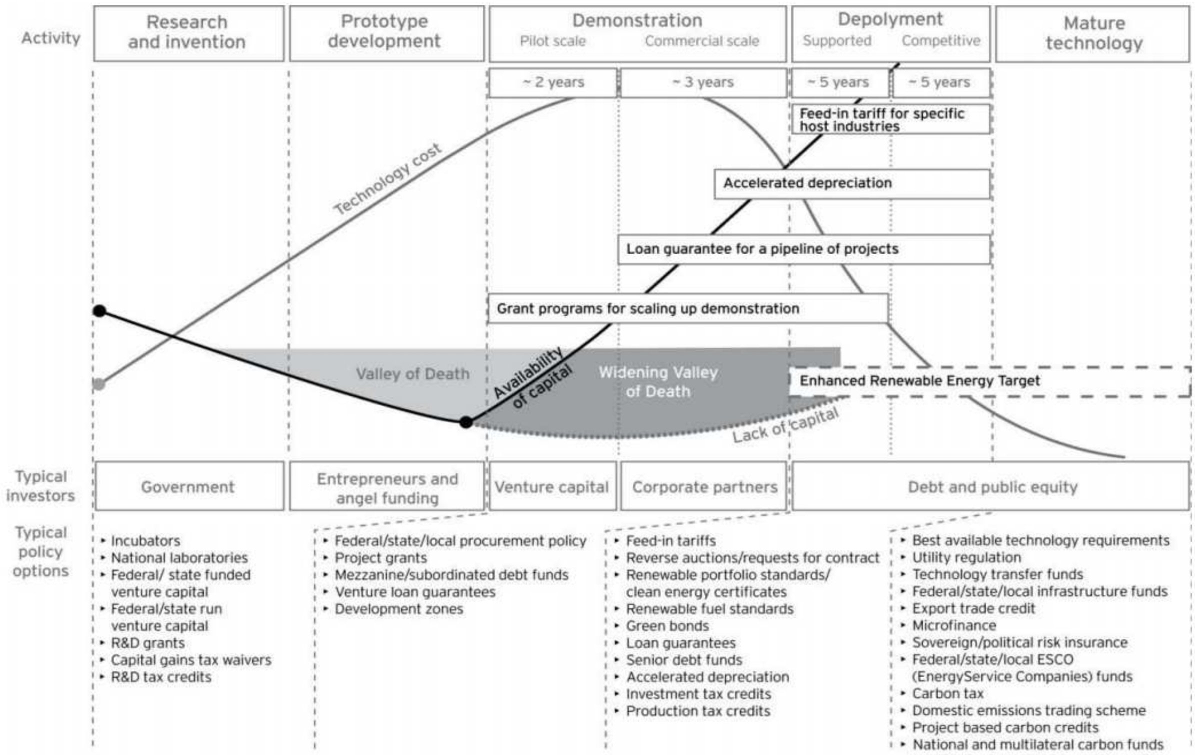
[47] In addition to the under-pricing of GHG emissions, these include the mispricing of: natural capital and ecosystem services; energy (in)security; worker health and safety issues associated with fossil fuels; public

innovation (especially energy generation).[48] Accordingly, public policy and public investment will be central to successful low-carbon innovation and transition, more so than for many other historical waves of innovation and technological transformation.

More specifically, getting the policy *mix* right is important to inducing low-carbon innovation. Carbon prices and strong support for innovation together give powerful incentives for change. Theory (Acemoglu et al. 2012), modelling (Fischer 2008; Fischer & Newell 2008) and empirical evidence (Popp 2006) show that an effective and efficient low-carbon innovation strategy would combine two complementary sets of policy instruments:

- one policy, or set of policies, to price, and/or regulate for, the GHG externality and other environmental externalities associated with fossil fuels; and
- another set of policies to target each link in the innovation chain, from R&D through to deployment. Figure 8, below, provides a sense of the policies and instruments suitable to each part of the chain (the policies should operate *simultaneously* since at any point in time a whole suite of technologies will be passing along different points in the chain).

Figure 8: The Innovation Chain, the "Valley of Death", and Policy Mechanisms for Each Phase



health impacts of fossil fuels (especially air and water pollution); amenity impacts of fossil fuels; and natural resource scarcity and rents.

[48] The OECD and IEA have described low-carbon technology R&D as "twice a public good" (Philibert 2004); they could have gone further than "twice".

Source: Ernst & Young (2010)

A comprehensive set of low-carbon innovation policies would cover all parts of the innovation chain. Inevitably, though, countries will tend to specialise more in some phases than in others according to their comparative advantages, just as they specialise in technologies according to their comparative advantages. Considerations of global priority areas for climate mitigation and future market opportunities will likely also shape the evolution of particular countries' innovation focus over time. These observations suggest a (very basic) three-dimensional framework for thinking about how a single country — in this case, China — could orient its innovation efforts:

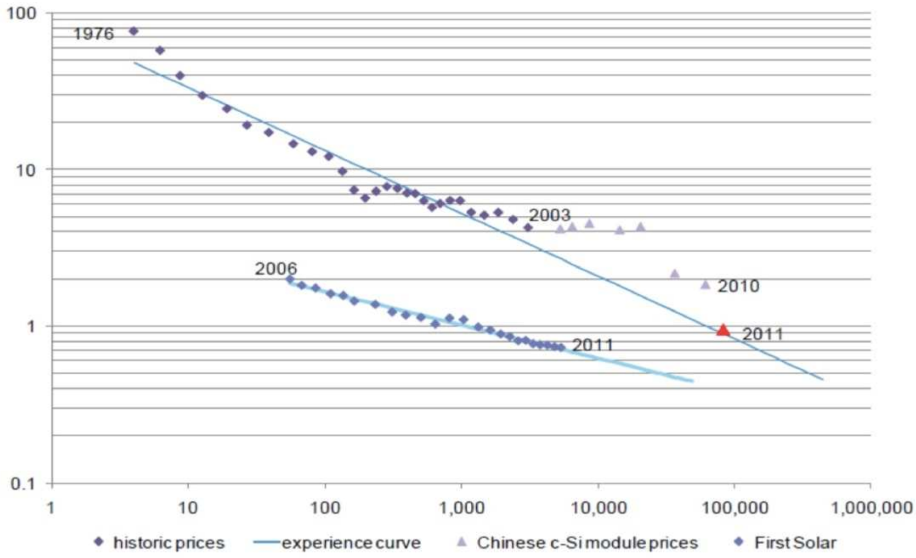
1. Phase of the innovation chain. For analytic simplicity, we here divide the chain into three parts:
    a. first — research and development;
    b. middle — demonstration, blending into early stage/supported deployment, where scale starts to become important; and
    c. final — deployment, with an emphasis on achieving cost reductions through scale economies and incremental manufacturing and process innovation;
2. Technology/industry;
3. Timeframe. Short-run innovation efforts will tend to focus on areas of existing comparative advantage, while in the long run countries' areas of comparative advantage will shift as they develop new capabilities, relative prices change, policy priorities change, and new opportunities/needs emerge.

Applying this framework, on which phases of the innovation chain and on which technologies/industries should China focus, and over which timeframes? Let us start by considering the world's low-carbon innovation needs and opportunities, and then compare these with China's current comparative advantages and its plans for the future.

In early 2012, the International Energy Agency (IEA) warned that the roll-out of a number of critical but less mature technologies with high potential for emissions reductions was lagging well behind what would be required to move onto a 2°C emissions reduction pathway (IEA 2012b). The IEA thus called for a focus most urgently on the demonstration and deployment of these key technologies — the last two parts of the innovation chain — with a view to bringing down the costs of these technologies to enable competitively priced emissions cuts over the medium-long term (IEA 2012b). The IEA and others have also warned of the need for at least a doubling of investment in the first part of the innovation chain for low-carbon technologies: basic research, applied research and technology development (IEA 2013b; Stern 2007).

China's current comparative advantages in innovation lie on the third part of the innovation chain: adapting and improving on technologies developed overseas, and achieving cost reductions through deployment at scale and incremental manufacturing and process innovation (Zhi et al. 2013), which it fosters through a wide range of support mechanisms across these areas (CPI 2013). This approach has achieved real successes (Zhi et al. 2013). It has enabled China to drive large price reductions for solar PV and wind (for solar, see Figure 9), with considerable global climate mitigation benefits (Grau et al. 2012; Wang, Qin and Lewis 2012); and it has established major shares in the global markets for these technologies.

Figure 9: Solar PV Module Cost Curve, 1976-2011



Source: Bazilian et al. 2012

Insofar as China's industrial structure evolves in line with its aspirations for higher value-added, high technology industries, and its skills advance relative to others, China will increasingly need to move towards the middle and first parts of the innovation chain, combining its later-stage deployment policies with a stronger "upstream" focus (see, e.g., Grau et al. 2012).[49] The case for China focusing increasingly on the middle part of the innovation chain is strengthened by the urgent global need for innovation focused on key, high-potential technologies — a need that China shares, assuming it wishes to reduce its coal use, meet its goals for sustainable economic transformation, and insure itself against grave risks of future climate damages. Logically, this is the next frontier for China as it restructures and develops its economy.

In addition to further innovation on solar PV and onshore wind, China (ideally in collaboration with other countries, as we explore further in section 5) could intensify its focus on a suite of key renewable energy, storage and vehicle technologies that both require support within the "middle" part of the innovation chain, as identified by the IEA (2012b; 2013b), and fall within China's portfolio of strategic emerging industries: concentrated solar power (CSP); offshore wind; electric vehicles; battery storage; and associated network infrastructure (electricity grid and battery charging). This will require a sophisticated mix of policies and investments.[50]

[49] Only a fraction of China's innovation activity has focused on basic and applied research in recent years (around 17% in 2009: Zhi et al. 2013).

[50] These are also crucial areas for synergies: vehicle electrification implies a growing demand for electricity and declining demand for oil; the full climate benefits of vehicle electrification will be achieved only if the electricity

The size of China's internal market means it has a special — arguably unparalleled — advantage of *scale* when it comes to fostering the maturation of these and other crucial low-carbon technologies. China's scale not only enables China to achieve price reductions through economies of scale: it also enables China to investigate different ways of doing things and to learn from such experimentation, and allows it to carry and spread the risks inherent in all forms of innovation. In the context of the global innovation deficit highlighted here, China's scale means it has a critical role to play in the global transition to a low-carbon world.

Let us take just two examples. Electric vehicles (EVs) present a huge market opportunity (Ward et al. 2012), but achieving maturation is complex, as it is beset by a range of technical (e.g. battery technology limitations), coordination, network infrastructural, and social/cultural barriers. Battery costs are critical to EV deployment, and these declined by 50% in the three years to 2013 (IEA 2013b). If current rates of progress continue, battery costs are on track to reach competitive levels by or before 2020 (IEA 2013b). However, intensified policy and investment support in battery technology innovation will be critical to achieving the necessary scale of emissions reductions, and in this regard China's special advantage of scale could play an important role.[51] Meanwhile, a rigorous focus on overcoming coordination, network and behavioural barriers through "learning by doing" from existing EV roll-out schemes, while enhancing capabilities to integrate cheaper battery storage options into electricity grids with higher renewables penetration, could help China to better prepare for a transition to an increasingly renewable-powered and electrified energy and transport system.[52]

China's scale is also crucial on solar. We have already noted the important role China has played in reducing solar PV costs. A further halving of costs would make solar PV competitive at scale in China, with great potential to meet much of China's expected electricity consumption, provided storage and system requirements can be overcome (Grau et al. 2012); this could be achieved with smaller cost reductions if even a modest carbon price were applied to fossil fuel energy sources. Intensified Chinese efforts, focused on growing China's domestic PV market through deployment targets and support policies, and more closely linking investment support to R&D criteria (to encourage the development of new PV technologies and options) would help greatly in achieving this goal (Grau et al. 2012). China's scale is similarly important to reducing global CSP costs. A number of developed (e.g. US) and emerging (e.g. South Africa) countries are scaling up their deployment of this critical suite of technologies.[53] China could intensify its support for commercial demonstration projects and deployment beyond its 2020 target of 3GW, with a view to scaling-up deployment in China's (very sunny) central and western provinces to support non-hydrocarbon-based economic development in

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is generated from non-fossil fuel sources, and the full benefits of grid integration of intermittent renewable energy can be realised only through the co-integration of vehicle-based battery storage.

[51] Some industry players are targeting aggressive cost reductions. For example, Elon Musk, CEO of Tesla, announced Tesla would invest in a $4bn-$5bn "gigafactory" to double the world's production of lithium-ion batteries, with the objective of cutting battery prices by 30% in three years and 50% by 2020 (The Economist 2014b).

[52] Even Formula 1 racing is now requiring hybrid engines, as showcased in the 2014 Australian Grand Prix (Gover 2014).

[53] There are four main CSP technologies. These are: Parabolic trough; linear Fresnel reflector; power tower; and dish/engine systems (NREL 2010).

those regions. Longer-term, large scale CSP plants in China's South-West and elsewhere could potentially supply eastern provinces via ultra-high voltage transmission lines.

Finally, for China to succeed in channelling its growing technical sophistication toward breakthrough innovations in low-carbon energy over the longer term — the first part of the innovation chain — 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). For example, China could establish well-funded energy research laboratories, modelled on those in the US, that are supported by a long-term (10+ years) research strategy[54] that empowers scientists and research managers with the academic freedom to take risks, fail and learn, and evaluates their performance accordingly (Anadon 2012; Zhi et al. 2013; Cao et al. 2013).[55] These institutions would be most effective if embedded within energy innovation clusters[56] that provide a legal and financial environment conducive to indigenous, early-stage innovation, and that have the "innovation ecosystem" needed to cultivate the interactions between researchers, entrepreneurs and venture capitalists that help facilitate the commercialisation of basic and applied research. This kind of enabling environment will help to ensure China's investments in R&D deliver the immense benefits that early stage low-carbon innovation can yield.

While China has established R&D clusters with significant concentrations in energy, participation in these clusters has been largely limited to SOEs, and the Government has not yet moved strongly to create specific mechanisms for integrating basic and applied research, or mechanisms to translate energy technologies into commercial products, disseminate information, or promote entrepreneurial activities (Anadon 2012). Overcoming this "gap" in China's R&D, demonstration and deployment efforts is likely to require both new government institutions to coordinate efforts in the early parts of the innovation chain, and the expanded participation of private, entrepreneurial technology firms and financiers. The Government's broader market and SOE reforms (CCCPC 2013, discussed in section 2) could therefore play a supportive, and potentially very important, role in developing an effective innovation ecosystem for breakthrough technological development.

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[54] Basic research needs to be supported by innovation policy strategy that is stable across Five Year Plans (e.g. for at least a decade). Zhi et al. (2013) identify shifts in priorities and levels of risk-tolerance from plan to plan as a key hindrance to past basic research initiatives in China.

[55] Zhi et al. (2013) identify the need for a culture of "higher risk-tolerance and a longer-term view", and for this to be reflected in managerial structures such as researcher performance evaluations. They also highlight the need to "[i]Increase the level of participation of scientists and entrepreneurs in the process of designing projects and awarding tasks."

[56] For example, Shanghai, Shenzhen, Suzhou and Beijing.

The benefits for China's economy and society of pursuing the measures outlined in this section could be very large. The aggregate effects (relative to a scenario in which they are not pursued) would likely include:

- Increased energy productivity;
- Increased total factor productivity;
- Greatly reduced air and water pollution, and associated reductions in human health and mortality effects and in environmental damage;
- Cleaner, healthier, safer, quieter, less congested, more productive, and more appealing cities;
- Increased energy security;
- Greatly reduced GHG emissions and associated risks of climate impacts;
- Greater equality through access to infrastructure, employment and a cleaner environment (particularly if the fiscal reform measures, discussed below, emphasise equity);
- Increased economic and social stability through reduced exposure to fossil fuel price volatility;
- Bigger markets for China's strategic emerging industries;
- Increased growth from innovation.

While some of these benefits (e.g. reduced risks of climate impacts) will accrue in the long term, the bulk of them would likely be realised in the medium term — within around 5-10 years, or the life of the next two five-year plans.

Nonetheless, achieving these benefits will require major structural changes, with some inevitable dislocation, in the short term. These pressures will add to, and interact with, a range of existing pressures and risks to China's growth, including the problems of overcapacity in property and heavy industrial sectors (including coal), and risks of defaults in the shadow banking sector (see, e.g., Sender 2014; Wolf 2014). Balancing the need for structural change as outlined with the need for shorter-term stability and growth will be a significant challenge.

This challenge underscores the importance of those measures outlined in this section that will also bring short-term economic and social benefits. Measures to increase energy efficiency, in particular, could bring benefits that accrue relatively quickly, improving factor productivity, creating jobs, saving money and resources, and boosting growth and welfare in the short term. The challenge also suggests a critical role for measures to manage the effects of restructuring and dislocation on the lives and livelihoods of those involved, including via income support, retraining, new opportunities and so on. Finally, it suggests the importance of a strategic, well-articulated and convincing approach to reform that can convince local households and firms about both the long-term direction of travel and its benefits, and the shorter-term management of change. These last two points are discussed further in the following section on fiscal and governance reforms.

4. Fiscal and Governance Reform to Deliver a Sustainable Structural Transformation

Achieving sustainable structural change of this nature and scale will require fiscal and governance reform to ensure that: (1) the right incentives are in place; (2) governments have the amount of revenue, and the appropriate revenue streams, necessary to carry out the expenditure programmes required; and (3) the revenues accrue at the appropriate level of government (directly, or through appropriate revenue sharing arrangements).[57] With these intermediate objectives in mind, we set out below a set of fiscal measures that China could implement to achieve the sustainable structural transformation we have sketched in this paper.

We note that these reforms are intended to address only the matters discussed in section 3 of this paper, and should be seen as complementary to the broader set of fiscal reform recommendations made by Ahmad, Rydge and Stern (2013), which also encompassed reforms to value-added tax, corporate income tax, personal income tax and excises. Further, we have not considered here how reform of China's SOEs (see section 2) could affect public finances. We note that the Central Committee's reform blueprint (CCCPC 2013), on the one hand, suggests a diminished role for SOEs (an implication of the expanded role of market-based, non-public capital allocation) but, on the other hand, SOEs will be expected to return an increasing portion of their revenues to the government for public purposes.[58] A movement from a planned economy with strong public ownership and command over resource allocation requires the replacement of direct control over resource allocation with incentives, market structures and regulation, and an efficient and equitable tax system capable of raising revenues necessary for public expenditures.

Fiscal Reform for Local Authorities

Providing local authorities with the right incentives to ensure sustainable spatial development, invest in sustainable infrastructure, and provide high quality public services to existing and new urban residents is a critical and urgent challenge. The rapid pace of urbanisation, together with the "lock-in" of urban structures, imply that the decisions local authorities take in the next decade will profoundly shape the quality of life in China's cities and the sustainability of its economy. Current fiscal arrangements leave municipal governments overly-dependent on revenues raised from fees and taxes levied when state-owned land is transferred and, accordingly, these arrangements perversely incentivise environmentally damaging urban sprawl through land conversion on urban fringes. The recent decline in relative revenue from transfer fees throughout China, and ballooning sub-national public debts, make this reform particularly urgent (Ahmad and Wang 2013).

[57] We focus on central and local governments here, though we recognise that provincial level reforms are also likely to be necessary.

[58] The Third Plenum decision (CCCPC 2013, [6]) states that the government will "increase the proportion of state-owned capital gains that are turned over to the public finance to 30 percent by 2020, to be used to ensure and improve the people's livelihood."

Two key fiscal reforms could help China move toward a tax system that provides a more dynamic[59] and robust revenue base for its growing cities.[60]

The first is a broad-based, low-rate tax on property values.[61] International experience from middle-income countries suggests that a well-designed property tax could potentially raise around 1-1.5% of GDP.[62] The revenue could be used to provide the essential public services needed to support China's growing urban populations, without discrimination based on residential registration, and in so doing would support the household registration reforms that China's leadership has foreshadowed (CCCPC 2013).[63] It would also enable local government debt risk to be rated more strongly, hence laying the foundations for a viable municipal government bond market that will be vital to raising finance for the investments in sustainable and climate-resilient urban infrastructure as China urbanises (Ahmad and Wang 2013). When the bulk of this new infrastructure has been built, as the current wave of urbanisation recedes — perhaps by around 2025 — property taxes will also provide an important source of revenue for capital maintenance.

Second, fiscal measures to price for local urban externalities, particularly those associated with transport — such as traffic congestion, accidents, air pollution (from exhausts) and road damage — would provide incentives to reduce these problems. They would also raise additional revenues, perhaps in the order of 0.5% of GDP,[64] to support the necessary infrastructure expenditure (Ahmad and Wang 2013). Successful congestion charging and other vehicle management initiatives in London,[65] Singapore and elsewhere mean that there is a wealth of international experience from which China can draw in implementing such schemes. It is likely that most such schemes do not charge fully for costs inflicted on others from vehicle use and that the revenue potential could be higher still.

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[59] In the literature on public finance the technical term "elastic" is used to describe a form of revenue that rises strongly with income. We can interpret "dynamic" as "elastic" here.

[60] More efficient own-source revenues are also needed for metropolitan areas and provinces — especially to replace the distortive and cascading business tax that is a constraint to doing business (Ahmad and Wang 2013; Ahmad et al. 2013).

[61] Ahmad and Wang (2013) note that China has myriad forms of property tax but, with the exception of pilot programs in Shanghai and Chongqing, private homes are exempt and the overall revenue from these taxes is very small. In 2012, revenue from these property measures was 137.249 billion RMB, accounting for only 1.2% of China's total tax revenue. They argue that a new property tax should be applied to self-built or commercial residential housing used for residential purposes. They discuss various possible design features and note some of the challenges that Shanghai and Chongqing have faced in their property tax experiments. They conclude that there is much work to be done to design an effective property tax system in China, but that this is an urgent and important task.

[62] Ehtisham Ahmad, pers. comm. 6 March 2014.

[63] According to Ahmad and Wang (2013), in order to meet China's urbanization needs, the Asian Development Bank (ADB) estimates that a sum of Yuan 3 trillion per year (~5% of GDP) will be needed for infrastructure and the package of support facilities — including hukou, education costs, social services and the like. The ADB estimates that in 2011 the third tier (sub-provincial level) affordable housing cost amounted to Yuan 1.4 trillion, of which only Yuan 103m came as a subsidy from the central government; the rest had to be financed by bank loans, developers and rather meagre local finance capabilities.

[64] Estimate based on consultation with international experts.

[65] For example, London's congestion charge raised £148 million in fiscal year 2009/10, which the Greater London Authority invests into improving transport in London (TFL 2014).

Fiscal Reform for the Central Government

A second urgent fiscal reform challenge, relevant for sustainability, is to provide incentives to phase-out coal — and more generally to shift away from unsustainable patterns of energy consumption, pollution and GHG emissions. And such incentives could help provide the central government with the revenues necessary to foster investment in low-carbon innovation and in sustainable and climate-resilient infrastructure, particularly low-carbon energy generation capacity and associated network infrastructure. This transformation can be achieved efficiently through taxation to correct GHG and environmental externalities, particularly from fossil fuel energy consumption. We focus here on coal, for reasons discussed in section 3(c), though ideally these measures would be applied to all fossil fuels.

Current resource-based tax measures generally, and on coal specifically, have been ineffective at curtailing demand and raising revenue to cover their externalities, and are in any case offset by large subsidies (Ahmad and Wang 2013). The Government is currently finalising plans to reform the existing coal resource tax by moving from a production-based to a value-added method of taxation, following a similar change to oil and gas taxation that occurred in 2011. This is a sensible first step (it is the use of coal that is the source of emissions), but the government has, encouragingly, stressed the importance of going further, taxing resource rents and environmental and carbon externalities more effectively (CCCPC 2013).

In this vein, a key policy mechanism that China could use to phase out its coal consumption and achieve the other objectives mentioned here could be, and arguably should be, a tax on coal consumption.[66] The coal tax we suggest would address the global GHG externality as well as the local environmental, health, and other externalities from coal. It could take the form of an excise that roughly approximates the social cost of these impacts (Ahmad and Wang 2013). Excises that target environmental and carbon externalities have the dual advantages of: (i) a greater environmental focus than a pure excise on production or consumption of some good; and (ii) lower complexity and administration costs than a pure emissions tax or emissions trading scheme (Ahmad and Wang 2013).[67] Though we focus here on coal, a similar externality tax should also be levied on other fossil fuels, with the excise levels reflecting different levels according to their carbon/environmental impacts (Ahmad and Wang 2013). An example of this type of measure is the differentiation of the excise between leaded and unleaded gasoline to discourage the former.

The price effect of such a tax would strongly incentivise substitution away from coal toward lower-carbon, lower-polluting substitutes. Combined with a clear coal phase-out target and associated regulatory measures, the tax would send a very powerful signal to phase out coal, and would increase the likelihood that the capacity is phased out altogether rather than “partial” solutions

[66] Taxation of externalities could be a critical element of a three-part tax structure for fossil fuel resources encompassing value-added, rent, and externalities taxation.
[67] We note that China introduced a number of carbon emissions trading pilot schemes in 2012 — in Beijing, Tianjin, Shanghai, Chongqing, Hubei Province, Guangdong Province and Shenzhen — with Shenzhen launching its platform in June 2013 (NDRC 2013). In the medium-longer term, therefore, a Chinese carbon emissions trading scheme could play a role in pricing the GHG emission externality directly.

being introduced that mitigate urban air pollution but increase coal use, GHG emissions and water stress.[68] The tax could rise gradually and predictably in order to ensure that firms and households expect high future taxes and can plan accordingly. In this way, long-run structural transformation would be incentivised, yet the short run effects on people and firms would be more moderate.

The revenues raised could contribute to public investment in low-carbon innovation and infrastructure, and in so doing incentivise private investment in these areas. To illustrate the potential revenue that such a tax could raise, consider first a tax rate that includes only the carbon externality. Assume a (nominal) social cost of carbon of US\$35/tCO_2,[69] which would equate to roughly a US\$95 tax per tonne of coal.[70] China's consumption of coal is currently around 3.7Gt of coal per year (BP 2013). Thus, a US\$95 coal tax raises around US\$350 billion per annum, or around 4-5% of China's GDP per year.[71] Adding to this tax rate a component to reflect the local costs of air pollution might raise additional revenue in the order of 3-4% of GDP.[72]

At around 7-9% of GDP, on the above calculations, the revenue from such a tax would be more than adequate for the innovation and infrastructure expenditures required for a strong and rapid transition to a low-carbon economy, especially if public funding is used to effectively leverage private finance. Such leverage could be enhanced through the development of a green investment bank, or a green investment arm in a potential future development bank. The presence of such a bank has the great advantage of reducing the risk perceived by private investors, since government policy is less likely to be volatile in relation to sectors in which the bank is involved. Further, such a bank can have strong convening powers when it is necessary to syndicate financial packages because it is more trusted than a private bank. It can also develop a body of specialised skills.

Through these price effects and investment channels, the costs of key, low-carbon substitute technologies for coal — especially solar PV, concentrating solar power, wind and nuclear — could be lowered over the medium term, just as these need to be increasingly deployed to replace the phased-out coal capacity and support additional demand, including from the electrification of transport. Naturally, the revenues raised from the tax would decline as China's coal use declines, but if the revenues were applied to low-carbon infrastructure and substitutes as suggested, then the structural transition could fund itself and the longer-term need for that revenue would dissolve. Such taxes might also lead to some expansion of the use of natural gas (which should have a significant

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[68] Such as expanding coal use in the less-populated Western regions.

[69] Such a price is currently suggested by US official calculations (Greenstone et al. 2013) but as Stern (2013) shows, its calculation is likely biased downwards.

[70] For comparison, the average of regional coal prices in 2012 was around US\$135 per tonne (BP 2013).

[71] Assuming Chinese GDP of roughly US\$8 trillion (at current prices) (World Bank 2013).

[72] A joint State Environment Protection Administration (China) and World Bank study estimated that the health damages of ambient air pollution in China totaled 3.8% of China's 2003 GDP, and coal consumption was the main cause of air pollution (WB/SEPA 2007). Incorporating other pollution-related damages, such as the health effects of water pollution, and damages to fisheries and crops, adds to this figure (WB/SEPA 2007). The joint World Bank and Development Reform Commission's *China 2030* report claims that air pollution costs China 6.5% of GDP, based on 2008 World Bank data (WB/DRC 2013, at p. 39). We use a revenue assumption of 3-4% here reflecting the narrower estimate (WB/SEPA) to be conservative, and on the assumption that about three quarters of China's air pollution is caused by coal consumption.

but lower tax burden for emissions since GHG emissions from gas are substantially less than for coal) and that could contribute to a phase-out of coal, but over the medium term the need to reduce emissions would require the phase-out of gas or the use of CCS.

All in all, the fiscal reforms and measures we illustrate at various levels of government, if well targeted, designed and set at appropriate and efficient rates, could raise, on a very rough estimate, between 8-11% of China's GDP (Figure 10).[73] The timing of the introduction of these measures would be for political and economic judgement. The use of revenue would be open, but there are arguments, to which we now turn, for mutually-reinforcing packages.

Figure 10: Extra revenue from new taxes for sustainable economic transformation (rough estimates and when "fully-fledged")

Type of tax	Object of tax	Revenue estimate (%GDP)	Jurisdiction	Possible expenditure of revenue (see note to table)
Property	Land value	1-1.5	Local	Public service provision; basis for bond market for sustainable infrastructure
Externality /corrective	Urban externalities (e.g. congestion)	<0.5	Local	
	GHG emissions	4-5	Central	Low-carbon innovation and infrastructure; structural adjustment
	Environmental/ pollution	3-4	Central	
Total		**8-11%**		

Note: whether any revenues should be earmarked is a much discussed question. Arguments for earmarking can be to support political acceptability of a package of reforms, or when the earmarked measure could produce a particularly strong incentive effect in a desired direction when coupled with these reforms.

A Principled and Pragmatic Package

The fiscal reforms outlined should also adhere to sound principles of public finance. They should be designed to achieve: (1) greater *efficiency* in production and more rapid innovation; (2) better *distributional* outcomes; and (3) greater *accountability* for expenditure (Ahmad et al. 2013). Aside from being normatively desirable, relative to standard analyses in public finance adhering to these principles will also be pragmatically necessary to build public and market support for the reforms, and to overcome political resistance from vested interests and the wider public.

[73] These figures are based on the rough calculations of potential tax revenues contained in the relevant sections of this paper, above, and from consultation with international experts on China and fiscal policy acknowledged in this section.

If the reforms are efficient, by definition the gains to the "winners" of reform should outweigh the losses to "losers" and it should be possible to identify and cultivate a coalition of support for the changes. Efficiency-enhancing tax reform should, moreover, generally be supported by the financial and business community. For example, well designed fiscal reform should improve China's investment climate, raise the productivity of capital and labour, and enhance China's attractiveness as a foreign investment destination, which will also accelerate China's structural shift toward services and high-end manufacturing in strategic industries, as discussed in section 2. Well-conceived taxes, moreover, can allow for reduction of the less sensible taxes (see Ahmad et al. 2013 for discussion).

Improving distributional outcomes, through the tax measures directly and via accompanying transfer payments where appropriate, will help to ensure that the poorer income segments are made better off, and that relative inequality (interpersonal, urban-rural and east-west) is reduced. For example, ensuring some of the revenues from carbon/environmental taxation are applied to assisting affected workers and communities find new sources of employment and income in the low-carbon economy is both a moral and a political imperative. It could also be used to protect poorer people from any associated rise in energy prices. If the dynamics of learning go well, then rises in energy prices might be temporary. And energy efficiency, for example, via insulation, is often the most effective way to protect poor people against rises in energy prices.

Greater accountability for spending, especially at the provincial and municipal/county levels (where growing liabilities are a major problem), will be essential to building trust among the public that the fiscal reforms will actually lead to the promised expenditures. For example, ensuring property taxation is clearly linked to the provision of basic services for all urban residents, and that local authorities will be held accountable for the delivery of those services, can help mitigate distributional and accountability concerns that might otherwise fuel resistance to the tax.[74]

Even if the reforms are efficient, fair, and the right public authorities are held accountable for their implementation, reform of this breadth and depth will be politically challenging. But delay will accentuate these challenges. Just like physical infrastructure, social, political and economic patterns also become increasingly "locked in" by existing policies and institutions. But there are reasons to think that bold reform is feasible. Boldness can be a virtue: tackling many complex and challenging reforms all at once as part of a reform "package" can actually be *more* effective than modest reforms done in isolation (Ahmad and Stern 1991). China has succeeded with the "package" approach to big fiscal reforms in the past, including the tax overhaul of the early 1990s, which laid the foundations for further growth and structural change in the 1990s and 2000s (see Ahmad et al. 2013). "Packaging" was also critical to the success of the Mexican Government's ambitious 2013 tax reform package, which rolled VAT, corporate income tax, carbon tax, energy pricing, excises, PEMEX reform, and a minimum basic pension into a single package.[75]

[74] Moving the land cadastre and property valuation responsibilities to the provincial level, while leaving rate setting at the local level (within a band) may be important in overcoming local incentives to cheat (Ahmad 2013).

[75] We are grateful to Ehitisham Ahmad, who advised on these reforms, for his description of this example.

There are at least two possible ways in which such “packaging” can make the politics of fiscal reform easier. First, when reform is undertaken across multiple dimensions that incorporate both efficiency gains and redistributive transfers, there is a greater likelihood of making more people absolutely better off *across the whole package*. In totality, the reforms outlined here have the potential to improve the lives of the vast majority of China’s population — and certainly those in the lower-middle income brackets — while protecting them against future shocks and risks. Second, whereas individual fiscal reforms and their justifications may be difficult for people to understand, packaging makes it easier for the government to embed disparate, technical reforms into a larger causal narrative whose principles and purpose are more easily understood and accepted (Gauri 2012, drawing on Kahneman 2011). China faces acute environmental, social, fiscal and governance challenges. The fiscal reforms considered here would go a long way to addressing many of these challenges. China’s leaders have an historic opportunity to lay the fiscal foundations to support sustainable growth and prosperity for many decades to come, and in so doing to tell a powerful story about China’s future. Action now can set China on a very attractive road; delay will make finding such a path much more difficult.

5. Innovation and China’s International Engagement on Climate Change

The measures discussed above would not only benefit China directly; they could also stimulate much greater global action on climate change, with consequent further benefits for China’s sustainable growth. This section explains how China could enhance the influence of its domestic measures through its engagement with other countries, including in the context of the forthcoming international discussions on climate change, and the additional benefits to China this engagement could bring.

China is no longer an emerging economy responding to global developments, but a major player that influences global developments. This is becoming increasingly evident in movements toward the low-carbon economy. China’s size, growth and action on GHG emissions also raise the global expectations about what China, along with other major emerging economies, will be able to contribute to future global climate efforts.

At the same time, emerging countries, including China, have been concerned about the possibility that formal constraints on emissions could undermine growth. Thus there has been some caution within China about setting its ambition concerning the scale of emissions reductions, even though experience and analysis increasingly suggest that large reductions are both possible and attractive.

There are two key changes in countries’ shared understandings and expectations regarding these issues that have been developing in recent years. First, there is a growing recognition of the potential for discovery, growth, technical change and improved quality of life associated with alternative, low-carbon paths. Thus there is an increasing movement beyond the (misleading) assumption that cooperation on climate change is only about sharing “burdens” and “costs”.

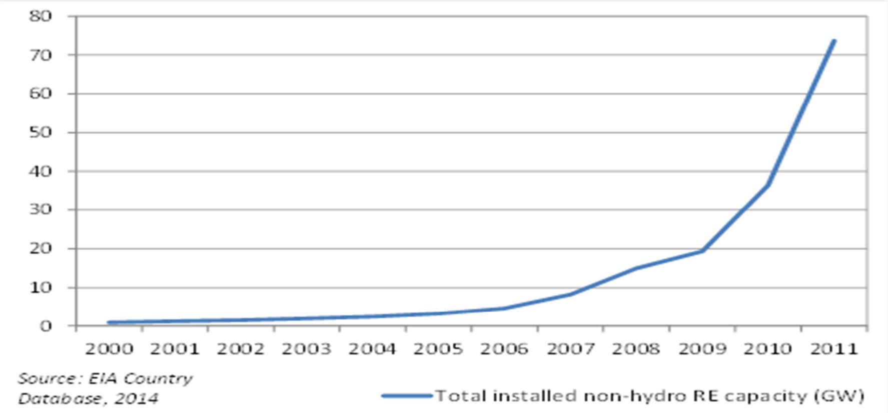
Second, since the Copenhagen conference in 2009, there has been a subtle but crucial shift in the focus of international climate cooperation toward a more *flexible, action-oriented, dynamic and* *collaborative approach* — an approach that is likely to be much more conducive to achieving agreement and progress among developed and emerging economies in general, and more inclusive toward China in particular. One way in which this has manifested itself is in the move away from the rigid binary distinction between "legally binding" and "voluntary" commitments, and towards a focus on the range of contributions that countries are making, and can credibly commit to making, toward the global mitigation effort. This shift has been driven by a combination of political realities in the United States and the major emerging economies that mean that treaty-based, and in this sense legally binding, emissions reduction targets are a political non-starter in key countries, and a recognition that formal "binding" targets are in any case not a good guarantee of mitigation action, let alone deep structural reform of the kind required. Internationally "binding commitments" can lack credibility, as Canada's defection from the Kyoto Protocol illustrates most starkly.

The converse is also true: contributions and commitments can be *credible* without being internationally binding. It is notable, for example, that the EU, the US and China look close to delivering on their 2020 emissions reduction pledges made in Copenhagen and formally adopted at COP16 in Cancun, even though these are not legally binding international treaty commitments. Credibility can be enhanced by (i) the nature, extent and feasibility of a country's expressed contributions; (ii) the measures, laws and institutions a country has in place to support and implement its actions or contributions; and (iii) the country's track record in climate mitigation.

By each of these measures, China's actions or contributions are highly credible. China has made numerous significant yet achievable climate-related commitments, including to reduce the emissions intensity of its economic output 40-45% below 2005 levels by 2020,[76] and these have been codified in China's central planning instruments, most prominently its 12th Five Year Plan. China's recent efforts to constrain the growth in its emissions are also evident from its unprecedented domestic roll-out of renewable energy. Between 2005–2011, for example, China grew from being tenth in the world to first for installed (non-hydro) renewable energy capacity (EIA 2014a; Figure 11). Moreover, China has a robust pipeline of climate policies that it is likely to expand upon as it develops its 13th Plan. Whereas some countries see their targets as aspirations, even when embedded in domestic instruments (for example, India's five year plans are aspirational documents), China's five year plans are strong domestic commitments against which leadership is judged and are supported by institutional structures to carry them out. And China has a good track record of setting and achieving ambitious economic and climate-related goals expressed in its central planning instruments.

[76] Notably, this commitment has been estimated to be *more* ambitious than the UK's fourth carbon budget commitment of a 50% absolute emissions reduction on 1990 levels by 2025, when the latter is translated into an emissions intensity target (equivalent to a UK 39% carbon intensity reduction below 2005 levels by 2020) (Bassi et al. 2014).

Figure 11: Total installed non-hydro renewable energy capacity in China, 2000–2011 (GW)



Yet these domestic policies and commitments are not always known, understood or perceived as credible by other governments. At present there is ignorance in many places over China's achievements to date and its plans for the future. This ignorance leads other countries to under-contribute on climate mitigation on the assumption that others are not acting sufficiently strongly. This predicament suggests that there is great potential for China to foster the international understanding, trust and confidence necessary to induce more ambitious commitments by others through more effectively communicating its emerging intentions as the 13th Five Year Plan develops. The forthcoming UN Secretary-General's High Level Summit on Climate Change in September 2014 provides an excellent opportunity for China to discuss with other countries the options it is considering, and to gauge other countries' efforts and expectations in the lead-up to the Paris COP in 2015, as do the bilateral China-US climate talks announced in April (Clark 2014). If other relevant agents — the key governments, investors, and foreign publics — come to understand that China's ambition is, or could be, very high, it will also materially raise their *expectations* that climate change can be tackled. The participation of leading Chinese research institutes in collaborative international projects, such as Tsinghua University's participation in the Calderón Commission,[77] should also help to bring global perceptions of the credibility of China's low-carbon plans closer to reality.

In this new international context, it would likely be in China's interests to prepare a package of the possible mitigation contributions it could make, expressed in terms of a target range of possible outcomes. Upper ends of the range could reflect ambitious yet achievable goals, although it would be recognised that these could not be guaranteed.[78] Specifically, announcing a range of scenarios to peak, phase out and tax coal, and for an absolute cap on China's emissions, could have a major positive effect on the global dynamics of climate cooperation.

[77] Information about the Commission, also known as the Global Commission on the Economy and Climate, is available from http://newclimateeconomy.net/. Stern is a Co-Chair of the Commission.

[78] It appears likely that other countries would be willing to accept expressions of non-binding contributions to the global mitigation effort in terms of such a range of possible outcomes. Whereas previously countries would typically commit themselves to as little as politically possible in order to maximise their chances of meeting their commitments (and avoiding the formal and reputational consequences of failure to do so), the more flexible approach that has emerged since Copenhagen effectively allows countries to indicate a minimum and maximum outcome without fear of adverse consequences if the maximally ambitious contribution is not achieved.

These dynamics would be further enhanced if China coordinated its approach with other emerging economies (e.g. within the BASIC group) and if that group linked its "upper bound" commitments to enhanced developed country action. Since perceived lack of action by emerging markets generally, and by China especially, is often used as a reason by developed countries for failing to take stronger action on climate change, expressing commitments in this way would make it more difficult for developed countries to shirk their even greater mitigation responsibilities arising from their high past and current emissions. China's rising coal use is often singled out by commentators and officials in other countries as a particular reason for inaction. A Chinese ambition to phase-out coal, linked to support and higher ambition from developed countries, could quieten such voices and lower the barriers in rich countries to stronger climate action.

Specific Chinese contributions on coal, along with other sectoral policies, measures and investments China is planning (and those suggested in this paper), would also lend themselves well to more intense collaboration on R&D, technology demonstration and deployment, finance, capacity-building and other practical projects across all levels of government. Such multi-level, practical collaboration is another emerging feature of the post-Copenhagen climate landscape on which China is well placed to capitalise further in the future. The demonstration and deployment of key low-carbon technologies currently at the high end of the cost curve — like electric vehicles / battery storage, CSP, and associated network infrastructure, which we highlighted in our remarks on innovation — make them ripe for this kind of collaboration, which enables the sharing of costs and risks, and the diffusion of knowledge and learning (IEA 2013b; Grau et al. 2012; World Bank 2012).

City level governments are playing an increasingly important role in global efforts to build a low carbon economy, as evidenced most prominently through the emergence of the C40 network of large cities, which has had demonstrable success in accelerating the transfer of knowledge and best practice across many of the world's largest cities, and in facilitating collaborative action (C40/Arup 2014).[79] As Michael Bloomberg, President of the C40 Board of Directors and now UN Special Envoy on Climate Action, has put it: "cities have the power, the expertise, the political will and the resourcefulness to continue to take meaningful climate action, and are, more than ever before, at the forefront of the issue of climate change as leaders, innovators and practitioners" (C40/Arup 2014). In line with the reforms of municipal level governance and fiscal structures outlined earlier, and their centrality in delivering many of the low-carbon measures we have highlighted, China's city governments would benefit greatly from increased participation in such collaborative endeavours.

A Chinese "high ambition" scenario of the kind we have sketched in this paper would itself bring numerous non-climate related benefits to China as well as materially reducing the probability of some of the worst climate impacts due to the sheer scale of the emissions reductions of which China is capable. We have also argued that higher ambition from China can help to foster higher ambition

[79] For example, the network's latest research, which compares city actions audited in 2013 with a similar audit undertaken in 2011 shows that the number of cities with bike share programs has grown from six to 36, and whereas Bus Rapid Transit systems were deployed widely only in South America in 2011, now 35 C40 cities have or plan on developing BRT systems and 57% of these are in the more developed northern hemisphere (C40/Arup 2014).

from other developed and emerging economies. This second, dynamic effect could dramatically improve the payoffs to China of high ambition on climate change through two channels.

The first channel is the dramatic reduction in risk of dangerous climate impacts that would result from such action. Analysts from Vivid Economics and elsewhere (Ward et al. 2012) estimated the risk-reduction benefits of a concerted action scenario (which we discuss for illustrative and not prescriptive purposes) in which (i) developed countries reduce emissions by 80% on 1990 levels by 2050; *and* (ii) the emerging market countries in the G20[80] ensure that emissions (except from land use change) are at 2005 levels by 2050 and emissions from land use change fall by 50 percent on 2005 levels. They found that the most likely (modal) temperature increase by 2100 in this concerted action scenario is 2.4°C above 1990 levels — almost a full degree lower than the most likely temperature increase if only developed countries take the action described (3.3°C) (Ward et al. 2012).[81] Such concerted action also greatly reduces the probability of extremely high (6°C or above) temperature rises this century and of substantial sea-level rise.

The same study used a number of economic models[82] to estimate the difference in economic impacts under the two mitigation scenarios outlined in the previous paragraph. The modelling exercise found that if developed countries act without emerging markets, then there is a 10% risk that damages to China in 2100 could be as high as 8–10% of GDP, but this range of damages declines to just 2–4% of GDP in the concerted action scenario (Ward et al. 2012). These conclusions are likely to grossly underestimate the differences in economic impacts associated with these two scenarios, since the models used incorporate damages from climate change that are implausibly small, exclude many important climate mechanisms and risks, and contain parameters that further exclude important economic impacts and interactions (Stern 2013). And they do not account in any serious way for the non-GDP dimensions of what is at stake, most notably the potential impacts on human lives and livelihoods through health, movement of people, conflict and loss of life (Stern 2013). As such, the benefits to China of concerted action — in the form of mitigation of risks to incomes and, more importantly, to human life and well-being — would likely be extremely high.

Whereas the first channel describes the benefits to China in terms of avoided risks of high impacts/costs, the second channel concerns the associated global economic benefits that would flow from effective cooperation on climate mitigation, of which China would be well positioned to capture a major share. Concerted global action of the kind described here would likely cause a dramatic boost in low-carbon technology investment as it becomes clear that the world is serious about a low-carbon transition. Such action could unleash a large wave of clean energy investment, innovation and growth — an energy-industrial revolution — which not only brings growth and prosperity, but makes

[80] The G20 Emerging Markets (or GEMSs) are Argentina, Brazil, China, India, Indonesia, Korea, Mexico, South Africa, and Turkey. These are the G20 countries that do not have legally binding commitments to reduce emissions under Annex B of the Kyoto Protocol and that, in 1990, the base year for the Kyoto Protocol, had a Gross National Income (on an international dollar Purchasing Power Parity basis) of less than US$9,000 per capita. All of the other countries of the G20 had a higher GNI per capita in this year (Ward et al. 2012).

[81] The median temperature increase is 2.7°C if emerging markets take action alongside developed countries, but 3.9°C if they do not.

[82] RICE, PAGE and FUND.

them sustainable in relation to the environment and the risks of climate change. This is the only plausible growth story over the medium and long term. An attempt at high-carbon growth will eventually destroy itself through the deeply hostile environment it would create.

China's renewed focus on low-carbon innovation, as we have discussed earlier, would leave it well-placed to benefit strongly from this wave of innovation-led growth and development. While China's potential to prosper and lead in particular high technology markets looks strong (Ward et al. 2012), focusing on single markets in isolation is likely to underestimate the potential gains for countries like China that could benefit from synergies across a range of emerging high-tech areas, such as renewable energy, electric vehicles, advanced information and communications technology, and advanced materials. In this way, it can be seen that ambitious climate policy in China that is clearly articulated and well-coordinated with other countries, and that spurs other key countries to move together on climate action, is highly complementary to China's ambitions to find a new path for growth.

In other words, a Chinese "high ambition" mitigation strategy, if it helps move other key countries with it, can be both China's climate change insurance policy and its high-tech export market development strategy.

6. Conclusion

Over the last three and a half decades, China has undertaken major structural reforms that have laid the foundation for subsequent long periods of strong growth. China's reform and opening up in the late 1970s produced the rapid growth of the 1980s. The fiscal reforms of 1993/94 laid the foundations for high levels of government investment and continued strong growth throughout the '90s and 2000s, and provided a strong basis for China to weather the Asian and global financial crises in the latter parts of these decades, respectively (Ahmad et al. 2013). Often written off by the international community, China's ability to identify, chart and implement the next round of reforms has seen the country take the world by surprise, time and time again.

As China looks to the future, it can see many threats. Natural resource pressures are already acute; the pollution of air, water and land is taking a severe toll on the health and well-being of its people, the productivity of its economy, and the nation's image in the eyes of the world; local-level governance and fiscal reform are urgently needed; and climate change threatens to worsen many existing environmental and social pressures, while China's GHG emissions place great pressure on the world's rapidly diminishing carbon budget. But China also sees great opportunities — the potential to develop high-value, high-technology and services industries, to innovate, and to lift hundreds of millions more people out of poverty through urbanisation, employment, and expanded social services.

In the face of these and other challenges and opportunities, China aspires to forge a more *sustainable*, *efficient*, *innovative* and *equal* path for its future growth and development (CCCPC 2013). This paper has suggested that only a low-carbon structural transition can enable China to achieve this aspiration. Such a transition, we have suggested, would be marked by deep improvements in energy efficiency; carefully planned, green and people-centred urban development; the phasing out of coal; intense support for low carbon innovation; wide-ranging fiscal and governance reforms that focus on taxing carbon and local environmental externalities; and intensified cooperative engagement with other countries and non-state actors regarding the normative, policy and practical dimensions of climate change.

This transition is eminently achievable. But it will require China to set its sights high and demonstrate once again is ability to identify and make radical reforms. A repeated theme of our analysis has been that *bolder is better*: the bolder and more comprehensive China's low-carbon sectoral and fiscal reform efforts, the more new benefits come into play. As China's low-carbon ambitions and actions intensify, China will likely see increasing pay-offs in terms of dynamic global cooperation, climate risk reduction, and low carbon technology export development. Moreover, the bolder and more comprehensive China's fiscal reforms — provided they are efficient, equitable and transparent, and embedded in a causal narrative about the nation's future prosperity — the more winners and supporters it is likely to mobilise behind its reform agenda, and the more convincing that agenda will be, including to the outside world.

This is a critical decade for China and the world. The actions taken in this period, we have argued, will profoundly shape China's growth pattern for many decades and, directly and indirectly, global climatic conditions for centuries. The next two years, as China prepares its 13th Five Year Plan and engages with the world in the lead-up to the Paris 2015 climate conference, will be decisive in determining the actions that follow. China has the creativity, the ability to decide and deliver, and the scale to show the world what the future can be.

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