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Chinese emissions peak: Not when, but how

Thomas Spencer, Michel Colombier, Xin Wang, Oliver Sartor,
Henri Waisman (IDDRI)

WHAT RESTRUCTURING FOR THE CHINESE ECONOMY?

The Chinese economic model has been extraordinarily investment and resource intensive, and has driven the growth in GHG emissions. That model is no longer economically or environmentally sustainable. Therefore Chinese policy-makers are faced with a trade-off between slower short-term growth and economic reform, *versus* supporting short-term growth but slowing economic reform. The outcome will be crucial for the transition to a low-carbon economy.

WHAT DO THE 13TH FYP TARGETS MEAN FOR DEEP DECARBONISATION PATHWAYS?

Overall, the 13th FYP (2016-2020) gives the impression of a cautious reflection of the new normal paradigm on the economic front, and a somewhat conservative translation of this shift into the energy and climate targets. Nonetheless, the 13th FYP targets set China well on the way to overachieving its 2020 pledge undertaken at COP15 in Copenhagen, and to potentially overachieving its INDC. It thus seems likely that China will achieve its emissions peak before 2030. However, the crucial question is not when China peaks, but whether the underlying transformation of the Chinese economy and energy system lays the basis for deep decarbonization thereafter.

TAKING UNCERTAINTIES INTO ACCOUNT FOR A BETTER ASSESSMENT OF THE CHINESE ECONOMY'S INFLECTION POINTS

Thorough assessments of the implications of the 'new normal' for Chinese emissions and energy system trajectories, taking into account the link with the Chinese macro-economy, are needed. Scenarios provide a useful framework and should focus on a number of short-term uncertainties. Most energy system and emissions scenarios published today assume a continuity of trends between 2010-2015 and 2015-2020, which is at odds with clear warnings of significant, and potentially very different, inflection points in the Chinese economy, depending on the policy choices and external drivers that emerge in the coming years. To explore uncertainties and different possible paths, the drivers of emissions trajectories should be examined in detail at a sectoral level.

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Institut du développement durable
et des relations internationales
27, rue Saint-Guillaume
75337 Paris cedex 07 France

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For more information about this document, please contact:
Thomas Spencer – thomas.spencer@iddri.org

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1. INTRODUCTION

China is the world's largest CO_2 emitter and crucial to mitigating climate change. China was the first emerging economy to present its 'nationally-determined contribution' (NDC) before COP21, in which it pledged to reduce its CO_2 emissions intensity of GDP by 60-65% by 2030; increase the share of non-fossil fuel energy in primary energy supply to 20% by 2030; and to peak its emissions by 2030 and make "best efforts to peak early" (NDRC, 2015).

At the same time, commentators and recent data are increasingly suggesting that China is experiencing important economic and energy system changes today. Preliminary data indicate that global CO_2 emissions from energy stalled again in 2015, after rising negligibly in 2014. Much of this is due to a slight decline of emissions in China. The recently announced target for the improvement of carbon intensity under the 13th Five-Year Plan (FYP) confirms that China is overachieving previous climate policy objectives for 2020 (see below).

Building on previous academic work by the authors (in Grubb *et al.,* 2015), this paper reviews the future prospects of the Chinese economy, emissions and climate policy, and draws international implications. It reviews the targets of the 13th Five-Year Plan (FYP) and places them in the context of emissions trajectories to 2030 and beyond. It concurs with recent assessments that China is likely to peak its emissions before 2030. However, it argues for a reframing of the issue: the question is not when China peaks, but why. Will China's emissions peak be reached in way that enables deep emissions cuts thereafter?

The paper is structured as follows. Section 2 reviews the Chinese macroeconomic context and its implications for emissions trajectories. Section 3 reviews recent evolutions in the Chinese energy system. Section 4 analyses the targets of the recently announced 13th FYP. Sections 5 to 8 analyse the drivers of future emissions trajectories for China, drawing implications for policy commitments such as the Chinese NDC. Section 7 concludes.

2. THE CHINESE MACROECONOMIC CONTEXT

A discussion of Chinese emissions pathways must begin with the Chinese macro-economy. Chinese emissions are driven by its economic structure. The Chinese economy is exceptionally dependent on investment as a central driver of growth. This investment has taken place notably in the real estate and infrastructure sectors, to support the massive urbanisation process. In turn, investment in materials and energy intensive manufacturing capacity (steel, cement and other basic materials) fed into the construction sector. In 2013, 60% of investment occurred in the real estate and manufacturing sectors (NBS, 2015). Dependence on investment only increased subsequent to the 2007-8 financial crisis, as the Chinese government unleashed a massive stimulus program: in 2010 fixed investment grew by 22.4% compared to 2009 (Datastream, 2015). As a result of this investment-and-industry led development model, Chinese emissions a predominantly driven by the industrial sector. In 2014, 56.6% of CO_2 emissions were attributable to the industrial sector (based on data from Enerdata, 2016).

China's growth model from 2001-2013 has been described as the "… strongest, most resource-intensive economic growth model the world has ever seen" (Garnaut, 2015). Indeed, the industry sector and in particular materials (steel and cement notably) are responsible for the lion's share of energy consumption and hence emissions (Table 1).

Table 1. Share of industry, steel and cement in energy demand, 2013

	Industry as a whole	Non-metallic minerals	Steel
Share of final energy demand	52.5%	9.8%	18.9%
Share of final electricity demand	67.1%	7.0%	13%
Share of coal demand	33.6%	8.0%	16.4%

Source: authors based on data from Enerdata (2016).

China's old growth model served it very well, and the phase of growth lasting from 2001, marking China's entry into the WTO, has been unprecedented. However, for a number of inherent and policy reasons this growth model is no longer sustainable, in economic but also social and environmental terms:

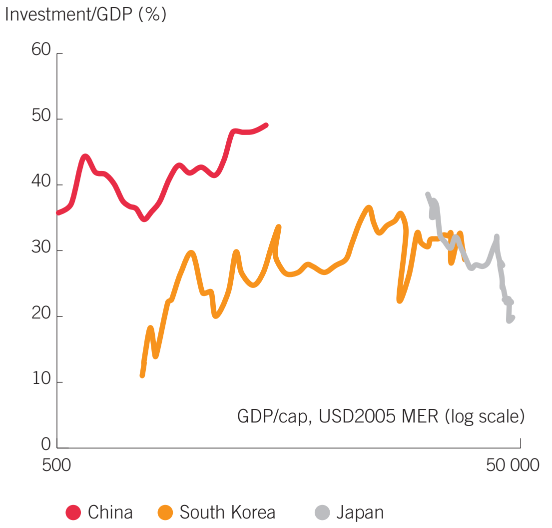
- *Less favourable environment for export-driven growth*: China's pool of low-cost, low-skill labour is being exhausted, removing the labour cost comparative advantage that China enjoyed. At the same time, global demand in advanced economies has weakened since the 2007-8 financial crisis and subsequent slow recovery.
- *Wasteful capital allocation and severe overcapacity*: as a result of massive investment in infrastructure and productive capacity, there is substantial overcapacity in multiple sectors from infrastructure, to real estate, to some manufacturing sectors. A continuation of economic growth based on investment would risk further wasteful investment in uneconomic projects (Lee, Syed and Xueyan, 2012). As China develops and shifts out of the infrastructure-intensive stage of development, its economy will need to rebalance away from investment and more towards domestic consumption. Related to this, China has a very high saving rate, which has fueled investment. This savings rate is likely to decrease due to population ageing and other factors, which would in turn have an impact on investment.
- *Growing debt*: the post-crisis investment boom was funded notably by the accumulation of corporate and local government debt. China's debt has quadrupled since 2007 to reach 282% of GDP (Dobbs *et al.*, 2015). This is one of the fastest growths in debt in economic history (historically, the rate of increase in the debt to GDP ratio is a good marker of the risk of financial crises). The concern is that much of this debt has gone into funding economically unprofitable real estate and manufacturing projects and may ultimately have to be written off (see Box 1). Further debt fuelled investment is not tenable.
- *New policy preferences*: the above described growth model led to rapid growth, but also to negative outcomes like significant environmental damage and economic inequality. As the Chinese population has become wealthier, the premium placed on clean air, water, and liveable cities is bound to increase.

The recognition that the old growth model was not sustainable has led to the promotion of what Chinese authorities describe as the 'new normal'. Briefly put, this involves slower headline growth and a restructuring of the economy away from investment and exports, and towards domestic consumption and services. This would have significant positive consequences for the energy and emissions intensity of its economy. Figure 1 describes the economic shift ahead: it shows investment as a share of GDP (vertical axis) in relation to the growth of GDP per capita (horizontal axis). The time series for the data is 1960-2013 in the case of China and South Korea, and 1970-2013 for Japan.

Three things are particularly salient. Firstly, it's clear just how historically exceptional China's level of investment/GDP is, compared to two other East Asian economies that have followed a similar highly industrialized development trajectory, namely Japan and South Korea. Secondly, it shows the 'Kuznetz curve' of investment/GDP relative to GDP/capita through the example of South Korea and Japan. Investment rises as a share of GDP as a country develops then peaks and declines as the economy shifts out of the phase of infrastructure, urbanization and industrial development and transition towards a more service oriented economy (although Japan and Korea still have high shares of industry in GDP, albeit lower than China today). It should be noted that these two points—the exceptionality of China's investment/GDP ratio, and the 'Kutznet's curve' profile of investment/GDP versus GDP/capita—also hold if the group of comparison countries is expanded beyond those shown here (Grubb *et al.*, 2015).

In summary: the Chinese economic model has been extraordinarily investment and resource intensive, and has driven the growth in GHG emissions. That model is no longer economically or environmentally sustainable. The shift towards a new economic model could have profound benefits in terms of reducing CO_2 emissions. The scale and speed of the transition is uncertain, however. We turn to this topic next.

Figure 1. Investment/GDP and GDP/capita, China, South Korea and Japan historic



Source: IDDRI based on data from World Bank (2015) and OECD (2015).

The path to economic rebalancing will not be easy. If the share of investment in GDP falls as it needs to, the share of growth in the productive capacity of the economy driven by capital accumulation will fall. This will mean that economic growth will need to be driven by growth in total factor productivity (TFP), i.e. this efficiency with which the factors of production labour, capital and natural resources are used. TFP can be thought of as a broad indicator of technology innovation. However, the most recent growth decompositions show that economic growth remains dominated by capital accumulation, with growth in total factor productivity stalling in 2014 (Conference Board, 2016). In 2014, the GDP growth attributed to capital accumulation was estimated at 7%, while TFP contributed -0.1%. It should be noted, however, that the two results are not independent of each other. If investment is non-productive, total factor productivity will fall. Less and smarter investment would see TFP rise. The challenge for China is that TFP may not rise fast enough to offset a significant fall in investment.

The discussion above concerned the growth of the productive capacity of the economy, i.e. the supply-side. Another way of looking at the Chinese economic transition is to look at the sources of aggregate demand: investment, household consumption, government consumption or net exports. The central government has some fiscal space to boost demand and continues an accommodative fiscal policy, although local governments are highly indebted. However, the risk here is that fiscal stimulus perpetuates the dependence on investment,

Box 1. Credit growth, capacity oversupply and the need for restructuring

As noted above, China has experienced a very rapid credit boom, most of which has gone to the corporate sector (of which a large share is state-owned). This credit has fuelled significant capacity explosion in a number of sectors from real-estate, to some manufacturing sectors, to the mining sector. Overcapacity in turn has driven down prices and corporate margins. This in turn raises questions about the ability of the firms in question to service their debt obligations. The IMF estimates that about 15.5% of bank loans are ‘potentially at risk’ (a loan to a company that has interest repayments higher than earnings before interest, tax, depreciation or amortization [EBITDA]). Loans potentially at risk are particularly concentrated in the real estate, construction materials and mining sectors. In turn, companies in these sectors have been turning to the bond market in order to access short-term funds (Figure 3). Ultimately, a reckoning cannot be delayed indefinitely. What is interesting for this paper is that the highly distressed, indebted sectors are those closely linked to a high carbon economic model. The imperative for reform and restructuring could lead to significant energy intensity improvements. At the same time the risks of delay and disruption are significant, and this would also have implications for the Chinese emissions trajectory.

Figure 2. Concentration of debt challenges in the steel, real estate, construction materials and mining sectors

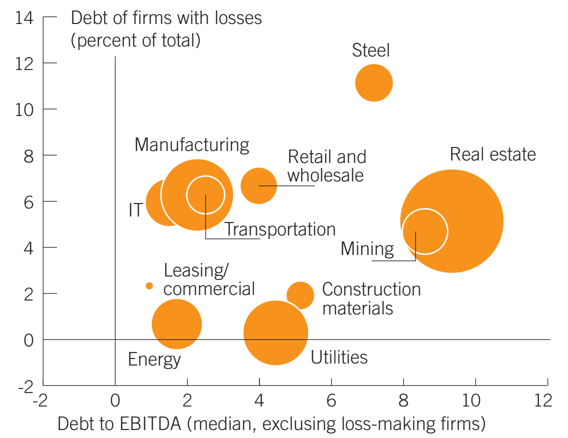
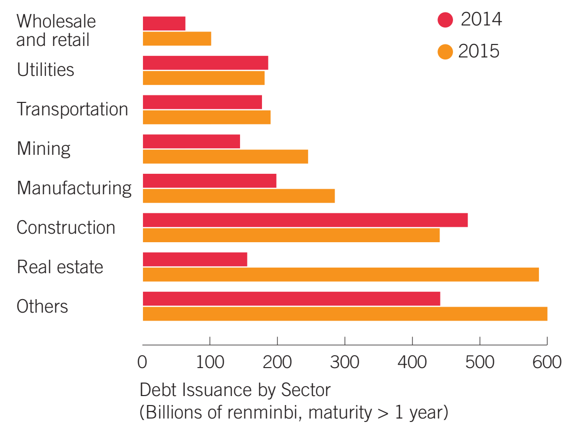
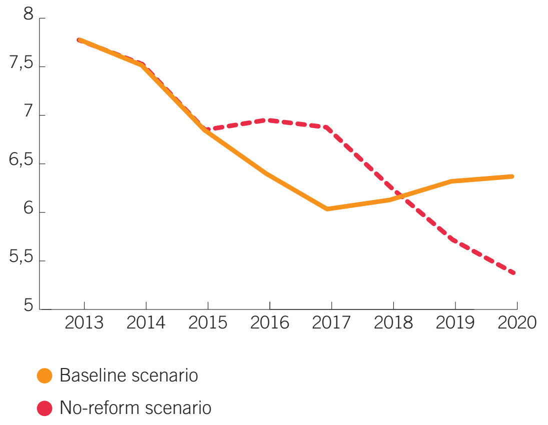


Figure 3. Bond issuance by sector



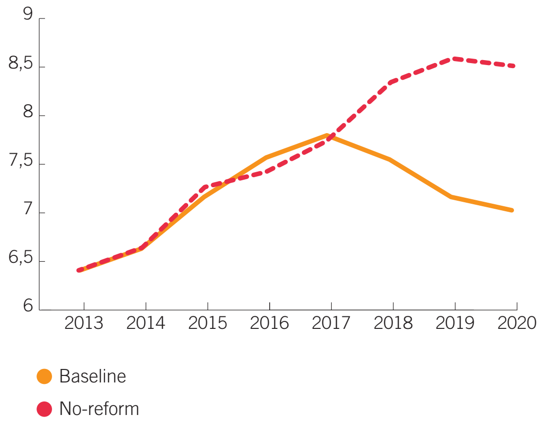
Source: IMF (2016).

Figure 4. GDP growth, baseline versus reform scenario



Source: IMF (2015).

Figure 5. Incremental capital output ratio (ICOR), baseline *versus* reform scenario



Source: IMF (2015). ICOR is an indicator for the efficiency of capital investment. The higher the index, the less productive the investment.

rather than promoting economic restructuring, unless it is targeted to sectors where supply is insufficient, notably health, education, social security and environmental protection.

With sluggish global demand, and particularly in advanced economies, it appears unlikely that net exports will provide a significant boost to growth. Moreover, an aggressive export strategy from a country the size of China would risk unleashing a wave of deflation across an already demand-deficient global economy, and reignite concerns of macroeconomic imbalances in the global economy and potentially currency wars or protectionism. The era of export-led growth is over. This leaves household consumption. Here we can see the beginnings of a transition. In 2014, final consumption (household and governments) accounted for 3.8 percentage points of growth, against 3.4 percentage points for investment. However, a question has to be raised whether China, with still relatively low income per capita and structural barriers to higher household consumption, can have significant consumption-driven growth in the short-term (Jin, 2015).

Broadly speaking, therefore, the 'new normal' policy agenda has three crucial objectives:

- Slowing down investment, or at least redirecting it from oversupplied sectors like heavy industry, real estate and infrastructure, and into undersupplied sectors like healthcare, education, information and communication technologies (ICT), and environmental protection. In addition, the legacy of overinvestment will have to be managed, for example through the closing of unprofitable facilities and bankruptcy of failing firms (as the 13th FYP intimates for overcapacity sectors like coal and steel).
- Boosting domestic consumption, for example through fiscal reform, and improving the social safety net (which can reduce precautionary saving).
- Boosting productivity and improving resource allocation in particular through innovation, efficiency and financial sector reform to promote a more market based allocation of investment (Anzoategui *et al.*, 2015). The latter is particularly important as it will contribute to both slowing investment, closing existing and avoiding further overcapacity, and improving productivity by allocating resources to their most productive use. A particular challenge will be dealing with the heavily indebted corporate sector (see Box 1). While sufficient prudential and fiscal buffers appear to be in place to deal with this in aggregate, the temptation will be strong for authorities to organise the roll-over of non-performing loans and delay the day of reckoning for the ultimate problem: non-profitable (often state-owned) firms in oversupplied sectors.

These reforms will not be easy, and Chinese policy makers have to balance the need for extensive reform and potentially painful restructuring, with the need to avoid a disruptive slowdown. In its report of the 2015 Article IV consultation with China, the IMF has provided two reform scenarios, one a baseline scenario including strong reforms, and another a 'no-reforms' scenario. This is not the place to engage specifically on the content or probability of these scenarios. **Rather, they provide a useful framework for exploring potential emissions and energy systems scenarios, taking into account the link with the Chinese macro-economy.**

Figure 4 and Figure 5 show the results of these scenarios. In the reform scenario, GDP growth drops significantly in the short term, before picking up towards 2020. In the no-reform scenario it remains higher in the short-term, before falling away as the challenges to the Chinese economy accumulate. Figure 5 shows that a no-reform scenario would involve an ever-rising (from an already high level today) inefficiency of capital investment. This scenario would likely leave China with an even more significant legacy of high-carbon capital stock, which would impede the low-carbon transition, both in practical but also in political economy terms (further locking China into a high-carbon economic system). The emissions and energy system consequences of these scenario frameworks are explored further below.

Thus the overall picture is one of a still nascent economic transition (Garnaut, 2015)**. The vast majority of the drop-off of investment as a share of GDP is still to occur (Figure 1), and other motors of growth are yet to kick in (total factor productivity and domestic consumption). In the short-term, therefore, reining back investment will be associated with a slowdown in growth. This is occurring today. Chinese policy-makers are faced with a trade-off between slower short-term growth and economic reform, versus supporting short-term growth but slowing economic reform. The outcome will be crucial for the transition to a low-carbon economy. What is interesting is the extent to which the energy system and CO_2 emissions have been impacted already, even at this early stage of economic restructuring (see below).**

3. THE CHINESE ENERGY SYSTEM CONTEXT

The Chinese energy system is starting to show the signs of significant changes, linked to the evolution of economic growth as well as the impact of clean energy policies. Clean energy policies are being driven by a combination of issues, including climate change mitigation, local air pollution, and energy security. Table 2 and Table 3 show leading indicators for the Chinese energy system as a whole, and the Chinese electricity sector specifically.

Several things are worthy of note in this data. Firstly, there are signs of a significant trend break in the growth rate of overall energy demand and carbon emissions, as evidenced by the slowdown in the growth of primary energy demand and electricity production in 2014 and 2015. As noted above, economic restructuring is still at an early stage, but a combination of slower growth particularly in energy intensive sectors has had a major impact on energy demand is recent years. Moreover, although progress has been made on the improvement of energy intensity of GDP and carbon intensity of energy, the Chinese energy system remains overwhelmingly based on fossil fuels (12% share of non-fossil fuels in primary energy in 2015 [NBS, 2015]). What is notable, however, is the drop off in coal consumption that has occurred two years in a row in 2014 and 2015. Table 3 also shows, however, the strong growth in low-carbon electricity supply sources in recent years (wind, solar, hydro and nuclear).

Table 2. China energy sector indicators

	Unit	2010	2011	2012	2013	2014	2015
Total primary energy consumption	Mtoe	2,587.8	2,801.7	2,908.4	3,010.5	3,073.2	3,100.9
Electricity production	TWh	4,208.0	4,715.8	4,994.0	5,447.2	5,665.1	5,682.1
Coal and lignite domestic consumption	Mt	3,229.9	3,717.4	3,857.8	3,991.7	3,875.8	3,732.4
Energy intensity of GDP	% change	-4.6%	-0.5%	-3.2%	-3.5%	-4.9%	-5.7%
Carbon intensity of energy supply	% change	-3.9%	4.8%	-1.7%	1.4%	-3.0%	-1.2%
CO_2 intensity of GDP	% change	-8.7%	3.8%	-5.3%	-2.6%	-7.6%	-6.7%
CO_2 emissions: fuel combustion	$MtCO_2$	7,362.0	8,355.8	8,521.8	8,894.5	8,987.9	8,947.6

Source: authors based on data from Enerdata (2016).

Table 3. China electricity sector indicators

Indicator	Unit	2011	2012	2013	2014	2015
Hydro capacity	GW	233.0	248.9	280.0	301.8	319,4
Nuclear capacity	GW	11.7	12.9	15.0	19.1	26,1
Oil capacity	GW	15.0	15.0	15.0	15.0	15,0
Natural gas capacity	GW	37.2	37.2	39.2	41.0	42,9
Coal capacity	GW	751.7	802.4	847.1	895.2	967,8
Biomass and waste capacity	GW	8.5	8.5	8.5	8.5	8,5
Wind capacity	GW	47.8	62.4	75.5	96.4	133,3
Solar capacity	GW	2.9	8.0	17.5	28.1	43,2
Carbon intensity of electricity	gCO_2/kWh	776.0	746.2	729.6	699.6	670,4

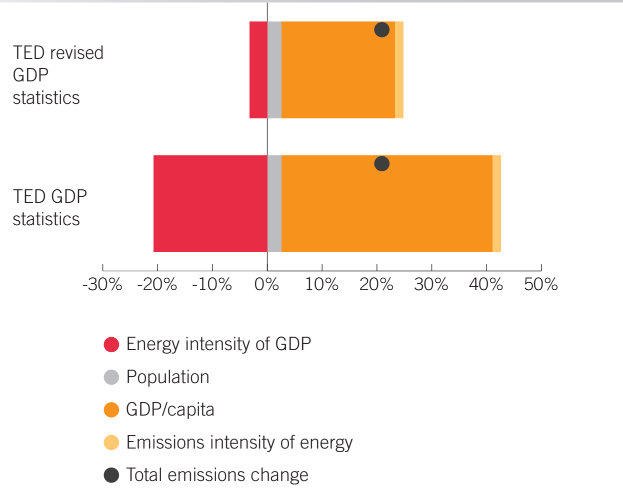
Source: authors based on Enerdata (2016).

One should be cautious about imputing the slowdown in emissions growth to profound structural change in China's economy or energy system.

Box 2. Implications of uncertainty in GDP statistics

There are a lot of uncertainties surrounding Chinese statistics, both as it pertains to energy but also GDP. Just as uncertainty in GDP statistics has complicated efforts to understand the drivers of GDP growth, so it may hinder an understanding of the historic and future drivers of CO_2 emissions. We can provide a brief analysis of the implications by examining two different breakdowns of emissions changes between 2010-2015. We use the so-called Kaya identity, which breaks down emissions changes into the product of changes in population, GDP/capita, energy intensity of GDP, and emissions intensity of energy supply. The analysis below uses two different GDP estimates. The first one comes from traditional Chinese GDP estimates from the Total Economy Database (TED) of the Conference Board, based largely on national statistics, and the second from a revised estimate of GDP based on the work of Wu (Wu, 2014), which are also provided in the TED of the Conference Board. GDP estimates are in USD_{2014} at market exchange rates. Figure 6 displays the results of the Kaya breakdown for emissions changes between 2010 and 2015 using the two different GDP measurements.

Figure 6. Kaya breakdown of emissions drivers for two different GDP estimates, 2010-2015



Source: authors based on data from Enerdata (2016) and Conference Board (2016).

Two quite different storylines emerge. With revised GDP estimates, growth dropped much more significantly after the global financial crisis. In turn, improvements in energy intensity were much lower over the period 2010 and 2015. On the other hand, using traditional TED GDP estimates, there have been impressive improvements in energy intensity of GDP, helping to offset a much faster rate of growth. In the first storyline, the post-crisis stimulus produced less and much more energy intensive growth. This might imply that there is a possibly larger potential for energy intensity improvement as the economy restructures. It also provides a further warning of the negative effects on energy intensity of the stimulus and investment led model that drove growth in the period 2010-2013. On the other hand, it should be noted that the two different GDP estimates give a quite similar estimation of energy intensity of the economy in 2015. The controversy over Chinese GDP statistics is by no means over, and this paper doesn't aim to take a position in this debate. Rather the brief discussion here demonstrates the need to dig into the fundamentals driving change (see Section 6).

Certainly, there are the beginnings of changes in the 'right' direction, but the majority is still to come.

Secondly, the carbon-intensive effects of the massive stimulus unleashed in 2009-2010 can be seen, with some lag as projects took time to implement, in the data for 2011: i.e. the slowdown in the decline in the improvement of energy intensity of GDP and carbon intensity of energy. This provides us a warning at the current juncture: efforts to prop-up investment and delay economic restructuring will have an impact on the improvement of energy intensity of GDP and carbon intensity of energy supply.

4. FIVE-YEAR PLAN TARGETS

The 13th Five-Year Plan (FYP) will provide crucial orientations to Chinese macroeconomic, industrial and climate/energy policy. With the documents just being released, this section aims to briefly discuss the main targets and their implications, in the light of the above analysis. Table 4 presents the main targets for macroeconomic and climate/energy policy in the 13th FYP.

Several things are worthy of note. Firstly, the 13th FYP envisages an acceleration of structural change with, firstly, a slowing of GDP growth and a slight slowing in the increase of the urbanization rate between the 12th and 13th FYP. Likewise, an acceleration of the shift to the tertiary sector is envisaged. Secondly, we can see increasing importance being placed in the role of innovation,

Table 4. Targets for the 13th Five-Year Plan

	12th FYP target (2011-2015)	12th FYP achievement (2011-2015)	13th FYP target (2016-2020)	Nature of target
GDP growth	7%	7.8%	>6.5%	Indicative
Tertiary sector's share of total GDP	47%	50.5%	56%	Indicative
Urbanization rate	51.5%	56.1%	60%	Indicative
R&D expenditure on total GDP	2.2%	2.1%	2.5%	Indicative
Contribution of technological progress to GDP growth	N.A.	55.3%	60%	Indicative
Share of non-fossil fuel to total primary energy consumption	11.4%	12%	15%	Obligatory
Energy intensity of GDP improvement across the five-year period	16%	18.2%	15%	Obligatory
Carbon intensity of GDP improvement across the five-year period	17%	20%	18%	Obligatory

Source: authors based on official documents.

with the indicator for R&D as a share of GDP, and the emergence of an indicator for the share of technological progress in GDP growth (although it is not clear precisely what this indicator relates to). This is consistent with the underlying story of the exhaustion of the old growth model based on the growth of factor inputs (labour and capital) and the need to improve the quality and efficiency of growth. Thirdly, the 13th FYP envisages the broad continuation of the energy and climate targets of the 12th FYP.

However, the energy and climate targets of the 13th FYP appear somewhat conservative when seen in the broader context of the Chinese economic shift. In the 12th FYP period China went through an extraordinary period of economic stimulus and investment in productive capacity and infrastructure, and still managed to overachieve its energy intensity and carbon intensity targets. The targets for carbon intensity and energy intensity of GDP have been scaled back in the period of the 13th FYP, compared to what was actually achieved in the period of the 12th FYP. At the same time, as discussed above, the 13th FYP envisages an acceleration of structural change in the economy.

Overall, the 13th FYP gives the impression of a cautious reflection of the new normal paradigm on the economic front, and a somewhat conservative translation of this shift into the energy and climate targets. Nonetheless, these targets set China well on the way to overachieving its 2020 pledge undertaken at COP15 in Copenhagen, and to potentially overachieving its INDC. The crucial question is their implication for the underlying transformation of the Chinese economy and energy system, and the implications thereof for longer-term trajectories toward deep decarbonisation. We now turn to this topic.

5. ILLUSTRATIVE EMISSIONS TRAJECTORIES – NOT WHEN BUT WHY?

In the light of the above discussion and analysis, this section presents some illustrative scenarios for Chinese CO_2 emissions. These are illustrative in the sense that they are intended to reveal the importance of different drivers of Chinese CO_2 emissions going forward, and to provide coherent storylines to think about the future of Chinese energy and climate policy. Full details for the scenarios are provided in the Annex.

In scenario 1 'strong growth', the growth objectives of the 13th FYP are met in the period 2015-2020, with growth of 6.5%/year in real terms. Strong GDP growth continues in the period 2020-2030, at a rate of 5.18% per year on average. It should be noted that this is significantly above other long-term projections from international institutions such as the OECD. In this scenario, China meets its 13th FYP targets for 2015-2020 in terms of the improvement of carbon intensity of GDP, which improves a total of 19% between 2015 and 2020. In the period 2020-2030, the improvement of carbon intensity of GDP accelerates slightly compared to the rate of improvement foreseen in the 13th FYP, and China peaks its emissions slightly before 2030. The internal tension or contradiction within this scenario comes from the growth assumptions, in particular for the period 2020-2030. Many observers consider a growth rate of 5.18% in this period as unlikely without thorough reform in the coming several years, which would slow growth in the short-term as well as inducing much faster energy intensity improvements. Nonetheless, this kind of scenario forms the basis of the Chinese INDC.

In scenario 2 'hard landing', the main determinant is slowing growth in the longer term, i.e. 2020-2030. In this storyline, short-term efforts to prop-up growth, for example through continued investment, slowdown restructuring and reform. In the short-term, GDP growth reflects the high end of 13th FYP objectives, averaging 6.72% in the period 2015-2020, before slowing considerably in the period 2020-2030 (4.03%/yr). Growth figures for the period 2020-2030 are taken from the long-term baseline projections of the OECD, developed in 2014 (OECD, 2015). In turn, the improvement of carbon intensity in the economy slows as well. The economy remains heavily dependent on energy intensive industries, and the political economy of replacing high carbon capital stock with low-carbon alternatives become more difficult in the context of slowing growth and an abrupt fall in investment. In this scenario, emissions peak earlier and lower than in scenario 1, but the main driver is slowing GDP growth. Subsequently, emissions plateau or decline slightly.

Scenario 3 'economic reform' represents a storyline of significant economic reform and adjustment. Growth is lower in the short-term, before picking up again towards 2018-2019. It then returns to the rate assumed in scenario 1 for 2020-2030. In the period 2015-2020, the carbon intensity of the GDP improves rapidly notably thanks to a faster improvement in the energy intensity of GDP at about 5% per year for the next several years (N.B. this is roughly the level seen in 2014 and 2015). Behind this improvement is a potentially painful adjustment, as unproductive and also heavily emitting factories and power plants are closed; the Chinese leadership appears to be preparing itself and the populace for this kind of situation (*Financial*

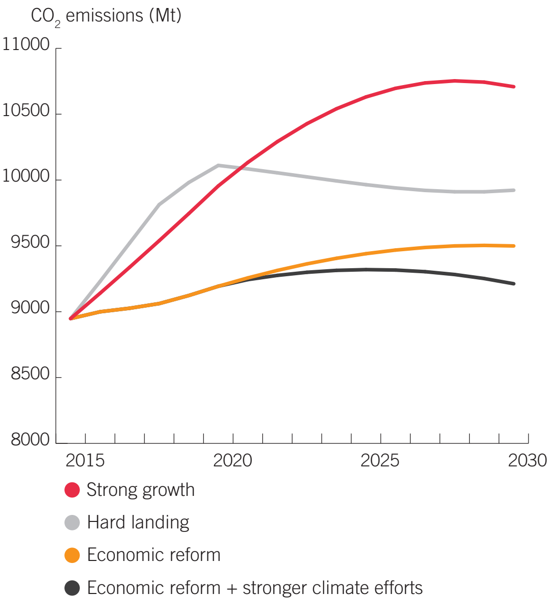
Times, 2016). In the longer-term the impacts of restructuring on the improvement of carbon intensity of GDP fade; in the decade 2020-2030 the improvement of carbon intensity returns to the level seen scenario 1. This level is roughly consistent with what is envisaged in the Chinese INDC. Because of this, emissions rise again from about 2020 and then peak in the middle of the decade as GDP growth slows in the latter half of the decade 2020-2030. This storyline can be thought of as combining elements of a 'new normal plus INDC': the emissions curve is bent downwards significantly in the short-term due to the new normal's impacts on energy intensity of GDP and slower GDP growth in the period 2015-2020.

This reinforces the point that it seems that the energy and climate objectives of the FYP are either conservative on the new normal's impact on energy intensity, or about the actual extent or reform and restructuring that will be seen in the decade 2015-2020. In which direction this contradiction is resolved represents the key difference between scenarios 2 and 3.

Scenario 4 'economic reform plus stronger climate efforts' takes essentially the same macroeconomic parameters as scenario 3. Scenario 3 assumed that the positive impacts of restructuring on energy intensity fade after 2020, and that the rate of improvement returns to that seen in scenario 1 (roughly consistent with the Chinese INDC). On the other hand, scenario 4 assumes that, through ongoing stringent efficiency and conservation measures, a slightly higher rate of energy intensity improvement is maintained in the decade 2020-2030. Moreover, through stronger efforts to decarbonize energy supply, notably electricity, scenario 4 assumes a slightly higher rate of reduction in the carbon intensity of energy in the decade 2020-2030, i.e. about -1.09% per year. This is above the historical average of 2005-2015 (-0.6%), but within the middle of the range of stringent climate action scenarios in the relevant modelling studies. It should be noted that in this scenario primary energy demand is significantly lower than in the 'strong growth' scenario, and therefore the *increment* of low-carbon energy required to achieve a reduction in the carbon intensity of energy is proportionally lower. In this storyline, emissions roughly plateau/grow slightly, and then peak and decline towards the middle of the decade 2020-2030 notably as the decarbonisation of energy supply starts to accelerate.

Figure 7 displays the results of the illustrative CO_2 trajectories for China. Annex 1 provides the key parameters for each scenario.

Figure 7. Illustrative scenario outcomes for Chinese CO_2 trajectories



Several things are worthy of note in the scenarios presented above**. Firstly, they are intended to show the importance of refocusing the debate away from *when* China peaks its emissions, to *why*.** Different drivers induce different levels of peaks, and also a different basis for further reductions going forward, in terms of the underlying energy and carbon intensity of the Chinese economy and energy system. Some scenarios, such as 'hard landing', peak for the 'wrong reasons', i.e. a significant growth slowdown, and still leave the Chinese economy with a relatively high energy and carbon intensity, not to mention an underachievement of development (growth) objectives. Driving further deep reductions after 2030 would be all the more difficult with this underlying basis of economic and energy system structure, and a potentially more complicated political economy in macroeconomic and climate/energy policy making.

Secondly, the scenarios point to the crucial importance of understanding the scale and impact of short-term economic restructuring on Chinese emissions trajectories. Between 'strong growth' and 'economic reform' there is not much difference in terms of energy and climate policy assumptions, particularly in the decade 2020-2030, but rather the divergences arise from shorter-term assumptions about the impact of the 'new normal' on GDP growth rate and energy intensity. **There are not enough 'new normal' energy system and CO_2 emissions scenarios that thoroughly explore the consequences of what the Chinese economy is currently experiencing and could experience over the next five years.**

Thirdly, it is premature to speak of the peak of Chinese emission today. Even in scenarios with significant economic reform efforts in the short-term, emissions could still follow a peak-plateau-increase-peak trajectory (cf. the 'economic reform' scenario). Moreover, the challenge of addressing emissions is likely to shift from the power and industry sectors, to the buildings and transport sectors. It is quite possible that an early peak could be driven by progress in power and industry, but with insufficient progress being made to sustain the peak in light of emissions growth from transport and buildings. Here the potential lock-in effects of long-lived infrastructure choices are crucial determinants of future emissions. Moreover, driving emissions reductions in these sectors will require regulatory innovation (shifting from controlling large point sources, to guiding the choices of hundreds of millions of consumers), and technology innovation to make available low-carbon alternatives in end-use sectors (e.g. hybrid or electric vehicles).

Fourthly, regardless of the economic reform efforts undertaken, driving deep reductions of emissions requires further climate specific policy efforts (cf. the difference between 'economic reform' and 'economic reform + stronger climate efforts' scenarios). In particular, this concerns continued efforts to maintain improvements in energy intensity, once the 'windfall' from economic restructuring has been reaped, as well as an acceleration of the decarbonisation of energy supply towards the end of the decade 2020-2030 (which, as noted above, will require a shift from decarbonizing electricity production to also decarbonizing final energy demand)

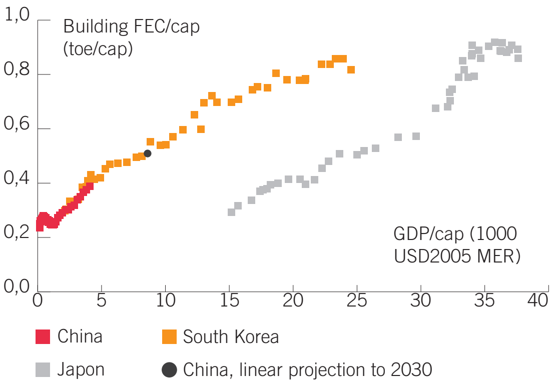
6. A SECTORAL ANALYSIS OF ENERGY AND EMISSIONS FUTURES

The above analysis in section 5 was based on 'top-down' assessments of emissions pathways, based on different assumptions of economic growth, energy intensity and carbon intensity of energy, informed by the literature (see Annex 1 for these assumptions). In this section, we provide a 'cross-check' based on a bottom up assessment. The purpose here is to use an alternative methodology, based on a sectoral assessment for the three major end use sectors: buildings, transport and industry. This provides us with two complementary layers of analysis. Firstly, it allows us to further investigate the drivers of emissions, at a higher level of sectoral detail, and thus explore the question of *why* emissions could peak to derive a more robust understanding of *when* and at *what* level they might peak. Secondly, it allows us to provide a 'stress-test' for the top-down analysis developed in section 5 (see Section 6.4). The GDP and population assumptions of this analysis follow that of the 'economic reform' scenario developed in section 5 above. Box 2 provides a brief discussion of some of the methodological limitations of the analysis conducted here.

6.1. Buildings

We can start with the residential and commercial sectors (buildings sectors). We start by benchmarking the level of per capita final energy consumption (FEC) from these two sectors in China, Japan, and South Korea, against real GDP/capita historically. Projecting the Chinese level forward to 2030 gives us a buildings FEC per capita of 0.52 toe/capita in 2030 (Figure 8). In turn, multiplied by the projected population of China in 2030, this gives a final energy demand for the buildings sector of 744.3 Mtoe.

Figure 8. Buildings FEC/capita versus GDP/capita, China, Japan, South Korea



Source: authors based on data from Enerdata (2016).

6.2. Transport

We now perform the same analysis for transport. Figure 9 shows the historical evolution of transport FEC/capita in China, Japan and South Korea.[1] It can be seen that the historical evolution in China

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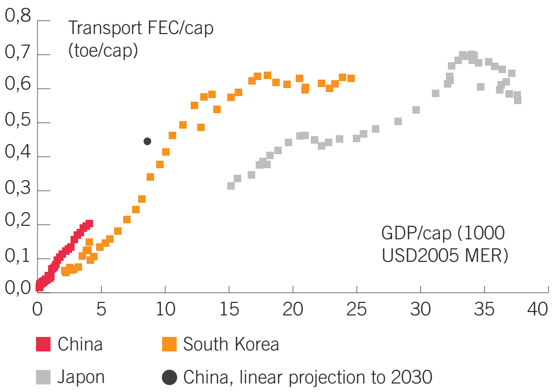
[1] It should be noted that the comparison here between China's neighbours, which are also similar highly industrialized countries, overlooks the fact that China has a much lower overall population density than Japan or South Korea. Population density can be an important driver of transport activity levels. However, the projection here is based on the historical relationship *for China* of transport FEC/capita versus GDP/capita. Japan and South Korea serve merely as reference points.

broadly tracks that of South Korea, albeit with a slightly higher energy intensity. This may be due to the lower population density of China, and larger landmass, which necessitates longer travel distances. Projecting forward the linear trend for China to 2030, we arrive at a transport FEC/capita of 0.45 toe/capita, which gives a total transport FEC of 634.9 Mtoe in 2030, a growth of 128% compared to the 2015 level.

Figure 9. Transport FEC/capita versus GDP/capita, China, Japan, South Korea



Source: authors based on data from Enerdata (2016).

6.3. Industry

We know turn to the industry sector. Here we combine an aggregate (i.e. monetary) analysis, with a physical assessment (tons of production) for the steel and cement sectors. There are large discrepancies in different databases and modelling exercises assumptions regarding base year (2010) industrial value added and industrial FEC. Some of these discrepancies are summarized in the table below.

Part of the discrepancy may lie in the 2015 revision of China's energy statistics, which revised upwards its energy consumption notably in the industry sector. This may explain the low number given the by the IEA (table 5 above)—IEA data displays a structural break between 2010 (725 Mtoe) and 2011 (919.3 Mtoe), which may be due to the fact that it has not yet been updated based on the revised national statistics. For the purposes of this paper we take World Bank data on industrial value added, and the base year data from the MILES project for industrial FEC. This gives us an energy intensity of industrial value added of 0.63 toe/1,000 USD_{2005} for the 2010 base year.

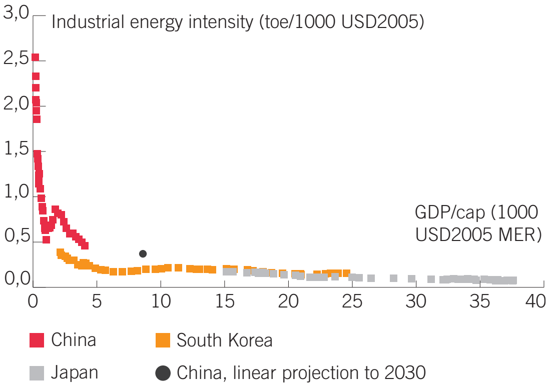
Table 5. Different estimates for industrial value added and final energy consumption in China, 2010

Source	Industrial value added (billion USD_{2005})	Industrial FEC (Mtoe)
Enerdata	1,590.1	936.8
World Bank	1,888.7	n.a.
DDPP project	1,855.7	1,232.2
MILES project	n.a.	1,187.8
IEA	n.a.	725.0

Source: Enerdata (2016), World Bank (2016), Spencer and Pierfederici (2015), LIU *et al.* (2015).

In order to provide an estimation of future industrial final energy demand, we make two assumptions. Firstly, following (World Bank and Development Research Centre of the State Council, 2013), we assume that the share of industry in GDP reaches 34.1% in 2030. In 2014, the share of industry was 42.7% of GDP, while the share of the tertiary sector was 48.1% (NBS, 2015). The target of the 13^{th} FYP is for a tertiary share of 56%. Assuming that the share of the primary sector continues its trend of slight decline from 9.2% in 2014 to 8.5% in 2020, this would mean that the share of industry in GDP would reach 35.5% already in 2020. A share of industry in GDP of 34.1% therefore appears a reasonable assumption to 2030.

Figure 10. Industrial energy intensity versus GDP/capita, China, Japan, South Korea

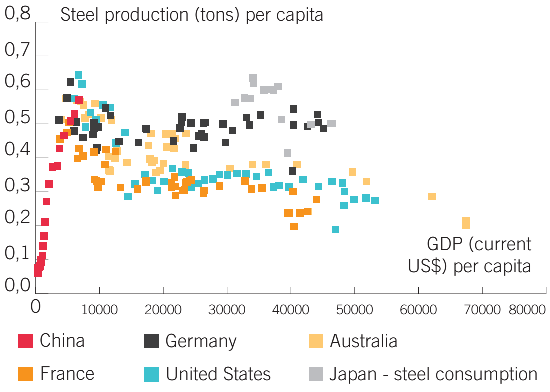


Source: authors based on data from (Enerdata, 2016)

The second assumption we make concerns the rate of improvement in industrial energy intensity. We assume that the energy intensity of industrial value added improves at 3% per year between 2010 and 2030. This is above the historical trend for the last 15 years (2.45%), but it should be remembered that this period was an extraordinarily resource and energy intensive phase of growth, which is coming to an end. The rate over the last five years has been 4.97%. In light of this, 3% per year across the period 2010-2030 appears reasonable, indeed perhaps a little conservative. This results in an energy intensity of industrial value added of 0.34 toe/1,000 USD_{2005} in 2030. This is still well above that of Japan and South Korea at comparable income levels (Figure 10). Multiplying this by the estimated industrial value added derived from the GDP growth assumption in the 'economic reform scenario' as well as the industry share of GDP, gives us a final energy consumption of industry of 1,461.6 Mtoe. This represents a 23% increase from the 2010 base year level assumed.

6.3.1. Steel

Figure 11. Steel consumption per capita versus GDP per capita



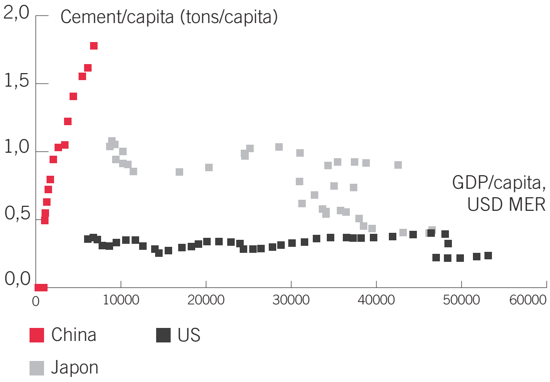
Source: authors based on Datastream (2015)

We turn now to the steel sector. The steel sector is widely acknowledged to suffer from significant overcapacity, and the 13th FYP makes restructuring and reducing steel sector overcapacity a priority. In early 2016, the Chinese State Council committed to reducing overcapacity in the steel sector by 100-150 million tons by 2020 (Xinhua, 2016). In 2015, China produced 803.8 Mt of steel (World Steel Data 2016), of which it exported 112.4 million tons, making China's steel consumption about 690 million tons.

Historically, steel consumption per capita has tended to follow the same kind of 'Kuzntez curve' pattern seen in Figure 1 for investment/GDP versus GDP/capita: as shown by the graph below (Figure 11). Let us therefore assume that Chinese long-term domestic steel consumption remains about 0.6 ton per capita to 2030, consistent with the kind of trends seen in Figure 8. Some countries like Japan are major exporters of steel, and so domestic production per capita is significantly higher than domestic consumption (0.86 ton production/capita versus 0.51 ton consumption/capita in the case of Japan—and much of that 'consumption' per capita is really for the export of products containing steel, such as cars and machinery). However, it seems unlikely that international markets would sustain such a demand for imported steel if a country as large as China were to maintain such an export surplus. Let us assume therefore a more modest export surplus of 0.05 ton per capita for China to 2030 (it currently stands at 0.08 ton per capita, and this is already producing significant deflationary pressures on world steel markets). This gives us a total production of 0.65 ton per capita in 2030.

This in turn equates to 923 Mt of steel production in 2030, i.e. some limited growth from current production levels. Assuming that energy efficiency of steel production continues to improve (in particular if the sector restructures towards producing more recycled steel) it seems probable that energy demand from steel could decline from current levels in the coming fifteen years. The story seen in this major energy intensive sector supports the idea that industrial restructuring could lead to rapid improvements in energy efficiency and slower energy demand growth to 2020.

6.3.2. Cement



Source: authors based on Datastream (2015).

We turn now to the production of cement. In 2013, China produced 2,414.4 Mt of cement, which equates to about 1.8 ton per capita. This is well above the historical range seen in Japan and the US, as can be seen from Figure 12 below. As a parenthesis, it is interesting to note the substantial drop off in Japanese cement production in 1991 (when GDP per capita was 28,540 USD): this was the date that the Japanese real estate and investment bubble burst. Observers draw a parallel between what happened in Japan in the early 1990s and the risk of an investment and real estate bubble in China today.

It therefore appears likely that the Chinese production of cement will fall in coming years. The speed at which this drop off occurs will be important in terms of defining the rate of energy intensity improvement in the industry sector in the 13th FYP plan period. Again, the story seen in this major energy intensive sector supports the idea that industrial restructuring could lead to rapid improvements in energy efficiency and slower energy demand growth to 2020.

6.4. Aggregation of bottom-up estimates and comparison with the top-down results

Having derived bottom up estimates for final energy demand in the buildings and transport and industry sectors, we now aggregate them in order to enable a comparison with the scenarios developed in section 5. Table 6 provides an overview of the main results, which are discussed further below.

Table 6. Aggregated results of the bottom up assessment

	Unit	2030
GDP	Billion USD_{2005}	12,511.3
GDP per capita	USD_{2005}	8,810.7
Share of industry	%	34.1
Transport FEC	Mtoe	634.9
Buildings FEC	Mtoe	744.3
Industry FEC	Mtoe	1,461.6
Total FEC	Mtoe	2,840.8
Assumed ratio final to primary energy demand (assumption)		1.35
Primary energy demand	Mtoe	3,835.1
Energy intensity of GDP	toe/1,000 USD	0.3065
Assumed CO_2 intensity of energy (assumption)	tCO_2/toe	2.53
CO_2 emissions	Mt CO_2	9,692.11

Source: authors.

Firstly, the bottom up assessment appears to confirm the top-down 'economic reform' scenario, compared to the higher emission 'strong growth' or 'hard landing' scenarios. Total CO_2 emissions reach 9,692.11 Mt, compared to 10,708.53 Mt in the 'strong growth' and 9,922.46 Mt in the hard landing scenario. This lends further evidence to the argument that China can peak its emissions earlier than 2030, and probably at lower level than envisaged in many scenarios. A key driver of the result here is the macroeconomic shift towards a lower share of industry, and restructuring within the industrial sector, which drives rapid improvements of energy intensity.

Box 3. Limitations of the bottom up assessment

Absence of an integrated model taking into account macroeconomic feedbacks: many of the relationships studied in this section are not independent. Most importantly, if the Chinese economy rebalances away from industry and investment towards services and consumption, this could have an impact on the share of national income going to wages versus profits, and hence the purchasing power of Chinese households. This in turn could mean that the historical relationship between GDP/capita and final energy consumption/capita in these sectors could change over time.

Business as usual assumptions for the transport and buildings sector. As noted above the assessment assumes a projection of historical trends of FEC/capita, and thus does not assume any further efforts to promote energy efficiency and control energy demand in these sectors.

Absence of a full energy model: as noted above figures like the primary energy demand and carbon intensity of energy had to be derived via exogenous and not independent assumptions, given the lack of an energy system model.

Any modelling exercise is a trade-off between complexity and transparency. The analysis here relies on very simple relationships and rules of thumb; what it loses in terms of complexity, it gains in terms of transparency on the drivers at play. A further layer of analysis and test is provided in section 7 below.

Secondly, the bottom up assessment leads to a slightly higher energy intensity than in the top-down assessment (0.3065 versus 0.3021 toe/1,000 USD_{2005}), and therefore to a higher primary energy demand in 2030 (3,835.1 versus 3,779.72 Mtoe). This also explains the slightly higher emissions seen in the bottom up assessment than in the top down assessment. Two factors may explain this. Firstly, the bottom up assessments assumes a 'business as usual' trend growth for buildings and transport energy demand, based on the historical relationship between GDP/capita and final energy demand/capita in these sectors. Achieving the rate of energy intensity improvement seen in the top down scenario may require moving beyond a merely linear projection of historical trends and towards more active energy efficiency policies in these sectors. Secondly, the assumed ratio between final and primary demand is a crucial assumption that must be made exogenously in the absence of a full energy balance model. The ratio assumed here is informed by the existing scenario literature, but is independent of other assumptions (i.e. the carbon intensity of energy). Given its importance to defining primary energy demand, it has a crucial impact on the energy intensity of GDP.

Thirdly, the bottom up assessment provides us with a further argument for the importance of investigating the drivers of change and prudence with regard to the recent stall in Chinese emissions. The analysis of the transport and buildings sectors highlights the degree of latent energy demand in these sectors, and hence the importance of progressively shifting mitigation efforts into this sectors. The analysis of the industrial sector highlights the crucial importance of assumptions on the macroeconomic share of industry in GDP, and structural change within the industry sector itself and its impact on industrial energy intensity. Here there is still much uncertainty.

The analysis in this section was intended to provide a simple, 'back-of-the-envelop' test for the top down analysis in section 5, in order to better highlight the relevant drivers of change. This bottom up assessment has a number of limitations that are further detailed in box 3. These do not invalidate the assessment here, but they provide further context for the parameters that need to be taken into account when considering Chinese emissions futures.

7. FURTHER COMPARISON WITH A 'DEEP DECARBONISATION SCENARIO' FOR CHINA

In this section, we provide a further test and layer of analysis, by comparing the results of the bottom-up and top-down exercises developed above with energy system and emissions scenarios developed using a structured energy system model. This scenario was developed by (LIU *et al.*, 2015) for the Deep Decarbonization Pathways Project (DDPP).

The objective here is not to invalidate this or that scenario, but rather to provide further light on the key assumptions driving scenarios and in that way inform an understanding of the possible trajectory for the Chinese energy system and emissions. In this way, we point to crucial assumptions that must be made explicit or studied further in future research efforts, as well as providing an understanding of the parameters to track and focus policy efforts on. We can also draw for ourselves a sense of what appears probable (and desirable from a policy perspective) within the range of assumptions taken by different scenarios.

Table 7 compares the main scenario results for the scenario developed in this paper and the scenario in the DDPP project.

Table 7. Comparison between bottom up scenario in this paper and DDPP scenario for China

Parameter	Unit	2030	
		This paper	DDPP
GDP	Billion USD$_{2005}$	12,511.3	13,332.8
Share of industry	%	34.1%	38.5%
FEC Transport	Mtoe	634.9	633.6
FEC Buildings	Mtoe	744.3	677.0
FEC Industry	Mtoe	1,461.6	1,869.0
Total FEC	Mtoe	2,840.8	3,179.5
Final energy intensity of GDP	toe/1,000 USD$_{2005}$	0.227	0.238
Energy intensity of industrial VA	toe/1,000 USD$_{2005}$	0.343	0.364
Rate of industrial energy intensity improvement, 2010-2030	%/yr	-3%	-2.99%
Steel production	tons	923	918.1
Cement production	tons	1,420	1,600
Carbon intensity of energy supply	tCO$_2$/toe	2.53	2.65

Source: Authors and LIU *et al.* (2015).

Table 7 reveals some important differences in results:

- *Macroeconomic assumptions on GDP growth rate*: the two scenarios result in different GDP levels in 2030 (a difference of 6.6%). This is due notably to the lower growth rate assumed in this paper for the period 2015-2020, as the Chinese economy transitions to the 'new normal' phase. This leads to a growth rate of 7% across the period 2010-2020 in this paper, compared with 7.2% in the DDPP scenario. Subsequently the two scenarios assume the same growth rate 2020-2030 (5.18%). This highlights the importance of assumptions about the translation of the transition to the new normal into short-term growth rates and their impact on long-term GDP levels.
- *Different assumptions on GDP structure:* the two scenarios diverge also in the assumption for the share of industry in 2030. This paper assumes a share of 34.1%, drawing on (World Bank and Development Research Centre of the State Council, 2013). As noted above, in 2014 the share of industry was 42.7% of GDP, while the share of the tertiary sector was 48.1% (NBS, 2015). The target of the 13th FYP is for a tertiary share of 56%. Assuming that the share of the primary sector continues its trend of slight decline from 9.2% in 2014 to 8.5% in 2020, this would mean that the share of industry in GDP would reach 35.5% already in 2020. A share of industry in

GDP of 38.5% thus seems a little at odds with the 13th FYP plans objectives. The DDPP scenario and the scenario developed in this paper are more convergent concerning the 2030 production of cement and steel. However, it is important to note that they diverge in the shorter-term to 2020. The DDPP scenario assumes a production of steel of 1,100 Mt in 2020, which seems at odds with the objectives of the 13th FYP of reducing steel overcapacity by 100-150 Mt from current levels. Regarding cement, 2013 production of 2,414.4 Mt was already above what is assumed for 2020 in the DDPP scenario (2,200 Mt), suggesting that cement production could start to fall already from current levels. These two data points for cement and steel suggest that a more rapid restructuring of the industrial sector, as foreseen in the 13th FYP, is not necessarily taken into account in the DDPP scenario for the period 2015-2020. If this restructuring eventuates, the result would be the kind of downward 'kink' seen in the emissions trajectory of the economic reform scenario in Figure 7, which is not seen in the DDPP scenario (which is pretty well approximated by the 'strong growth' scenario).

- *Different assumptions on carbon intensity of energy*: the two scenarios arrive at quite different levels of carbon intensity of energy in 2030. A particular challenge relates to uncertainty over base year data. The DDPP scenario assumes a carbon intensity of 3.286 tCO_2/toe in 2010, reducing to 2.903 tCO_2/toe in 2020, and 2.647 tCO_2/toe in 2030. By contrast, the most recently available international data estimates a carbon intensity of energy of 2.89 for 2015 already (Enerdata, 2016). The most recent IEA data estimates 2.99 tCO_2/toe in 2013, which would equate to 2.92 tCO_2/toe in 2015 if we assume that CO_2 intensity of energy has reduced by 1.1% per year over the last two years. Two crucial points emerge here. Firstly, the divergence in base year assumptions for 2010 can make a significant impact on longer-term trajectories; this is particularly important given China's recent substantial revision to its energy statistics. Secondly, the impact of short-term improvements in carbon intensity of energy between the last several years and 2020 can lead to significant divergences between different scenarios, even if these scenarios assume similar longer-term improvements in the carbon intensity of energy to 2030. As a final point, it should be noted that in the scenario developed in this paper, energy demand is lower in 2030: a smaller denominator would require a smaller numerator to achieve a given level of carbon intensity of energy supply.
- *Different results in the building sector*: it is notable that the DDPP scenario assumes much lower energy demand in the buildings sector compared to the scenarios developed in this paper. This is despite the fact that the scenarios in this paper assume a 'business as usual' trend growth for buildings sector energy demand.

Overall the results of this comparison do suggest that a strong translation of the 'new normal' in the period 2015-2020 could lead to significantly different emissions outcomes than is assumed in the 'strong growth' scenario, if slightly slower growth, more rapid restructuring and energy intensity improvements drive lower energy demand growth in the short-term. This potential does not seem to be translated into the DDPP scenario. This provides further evidence for the potential for a lower and earlier peak of Chinese emissions. It also militates for a more in depth analysis of energy system and emissions scenarios that explicitly try to represent the transition to a new normal in the short term.

8. CONCLUSIONS

This paper has explored recent trends and literature on the Chinese macroeconomy, and climate and energy policy. It has also discussed the targets and orientations of the 13th FYP within this context. Four overarching conclusions can be made.

Firstly, it seems highly likely that China will overachieve its 2020 and 2030 targets, and peak its emissions before 2030 and possibly at a lower level than often assumed. In that, the paper joins the conclusions of other recent analyses (Green and Stern, 2016; Grubb *et al.*, 2015). This is something that can only be welcomed from the perspective of fighting climate change.

Secondly, the paper argues that the debate on the timing of the peak is misplaced: what matters is not when by why. For the peak to be seen as a harbinger of deep transformation, it needs to be based on significant macroeconomic reform and restructuring, with attendant improvement in energy intensity, and continued efforts to maintain energy intensity improvements as the windfall from restructuring unwinds, and to accelerate the decarbonize energy supply. There are other scenarios in which China peaks even well before 2030, but on the basis of a less conducive underlying transformation of its economy and energy system, and/or for the 'wrong reasons' (notably, slower growth). Moreover, it is quite possible that Chinese emissions follow a peak-plateau-increase-peak trajectory, if for example the windfall from restructuring is not followed with continued accelerated climate policy efforts to decarbonize energy supply and use, and to maintain rates of reduction in energy intensity. This is a particular concern in the context of a foreseeable shift in the abatement challenge from the power and industry sectors to buildings and transport.

Thirdly, this paper contains a plea for thorough assessments of the implications of the 'new normal' for Chinese emissions and energy system trajectories. This assessment should focus on a number of uncertainties, in particular: the rate and structure of growth; the risks of efforts to prop-up growth and investment on the restructuring of the economy and knock on effects on the improvement of energy intensity and lock-in into high carbon energy supply infrastructure; and the energy system implications of significant macroeconomic restructuring in the coming 4-5 years. Most energy system and emissions scenarios published today assume a continuity of trends between 2010-2015 and 2015-2020 which is at odds with the clear and growing voices of macroeconomists warning of significant, and potentially very different, inflection points in the Chinese economy, depending on the policy choices and external drivers that emerge in the coming years. What happens in the short-term matters deeply in a country like China for the emissions trajectories to 2030 and beyond. There is much uncertainty on this front.

Fourthly, important uncertainties derive from the uncertainty about historical data, notably for base year (2010) GDP, industrial value added, primary energy and emissions. These can have significant impacts on longer term emissions scenarios. Efforts should of course be made to continuously improve statistical transparency and accuracy, and to translate that into international statistical databases like the IEA. However, this paper has also argued the need to examine in detail the drivers of emissions trajectories at a sectoral level. This can help to resolve some of the uncertainties that derive from statistics, but also creates new demands for different kinds of data and analysis. ▮

ANNEX 1: MAIN SCENARIO ASSUMPTIONS

GDP per capita (USD2005/cap)	2015	2030	2020/2015 annual change	2030/2020 annual change
Strong growth	4,067.0	8,910.8	6.05%	5.03%
Hard landing	4,067.0	8,068.7	6.27%	3.88%
Economic reform	4,067.0	8,810.7	5.81%	5.03%
Economic reform + climate stronger efforts	4,067.0	8,810.7	5.81%	5.03%

Energy intensity of GDP (toe/USD)	2015	2030	2020/2015 annual change	2030/2020 annual change
Strong growth	0.0005562	0.0003406	-3.20%	-3.23%
Hard landing	0.0005562	0.0003388	-3.40%	-3.18%
Economic reform	0.0005562	0.0003021	-4.50%	-3.73%
Economic reform + climate stronger efforts	0.0005562	0.0002995	-4.50%	-3.81%

Carbon intensity of energy supply (tCO$_2$/toe)	2015	2030	2020/2015 annual change	2030/2020 annual change
Strong growth	2.885503	2.4967789	-0.88%	-1.00%
Hard landing	2.8855039	2.5661865	-0.58%	-0.88%
Economic reform	2.8855039	2.5272085	-0.88%	-0.88%
Economic reform + climate stronger efforts	2.8855039	2.4741724	-0.88%	-1.09%

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