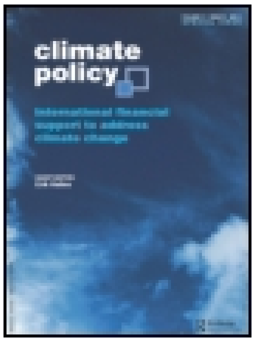

Climate Policy

ISSN: 1469-3062 (Print) 1752-7457 (Online) Journal homepage: http://www.tandfonline.com/loi/tcpo20

Exploring linkages among China's 2030 climate targets

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http://dx.doi.org/10.1080/14693062.2015.1124752

climate policy

research article

Exploring linkages among China's 2030 climate targets

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China published its Intended Nationally Determined Contribution (INDC) to the UNFCCC on 30 June 2015. In this document, China promised to reach its CO_2 emissions peak no later than 2030, reducing its carbon intensity by 60–65% by 2030, relative to the 2005 level, and to increase the share of non-fossil fuels in primary energy consumption to 20% by 2030. Using a simple method and official data, this article aims to explore the linkages among these three targets. First, it shows that as long as China achieves its 2030 non-fossil fuel target, its carbon emissions peak can be attained prior to 2030. Second, it provides a panoramic view of the link between carbon intensity and non-fossil fuel targets with different levels of GDP growth rate and energy elasticity. This article also presents further conclusions based on this finding: first, that a GDP carbon intensity target may help to control the absolute level of the carbon emissions peak, but it could be inconsistent with the development of non-fossil fuel power; and second, that a GDP energy intensity objective, together with a non-fossil fuel target, is necessary to ensure target coherency.

Policy relevance
The carbon emissions peak and the non-fossil fuel share of the energy mix can be considered as two key pillars of China's post-2020 climate pledges under the UNFCCC negotiation framework. It is therefore important to understand the relation between the two targets. This article uses a very simple non-modelling approach to demonstrate the implications of the achievement of China's non-fossil fuels target in terms of its carbon emissions peak and the linkage between achieving carbon intensity and non-fossil fuel targets under different growth and energy elasticity assumptions. Without focusing on the relevance of peak level or time, the authors illustrate the relationship between the 2030 non-fossil fuels target and the carbon emissions peak, highlighting the potential inconsistency between GDP carbon intensity and non-fossil fuels targets. These findings should have both political and academic uses to enable further clarification and analysis of China's INDC.

Keywords: 2030 emission peak; China; non-fossil fuel target

1. Introduction

The US and China published the US–China Joint Announcement on Climate Change[1] on 12 November 2014 in Beijing during the Asia-Pacific Economic Cooperation meeting. For the first time, the US and China – the world's two biggest GHG emitters representing 16% and 26%, respectively, of the total global energy-related emissions in 2012 (IEA, 2015) – put their domestic climate actions and

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targets for the post-2020 period into an international bilateral announcement. In this announcement, China promised to reach a CO_2 emissions peak by around 2030, to make major efforts to peak even earlier if possible and to increase the share of non-fossil fuels in its primary energy consumption to around 20% by 2030. These objectives were reconfirmed in China's recent publication of its INDCs to the UNFCCC on 30 June 2015, along with a further target of abating carbon intensity by 60–65% by 2030 relative to the 2005 level. These three objectives are central climate policy targets for China. It is therefore important to understand the way in which they interact.

There are some studies that focused on the interaction among climate policies. Liu, Gu, Wang, and Liu (2015) adopt a linear method to demonstrate how the implementation of carbon emissions trading in China would require adjustments to the level of feed-in tariffs accorded to renewable energy in order to ensure a maximal level of social welfare. Buckman and Diesendorf (2010) examine the design limitations of the Australian renewable energy market, and one of their analyses argues that the emissions trading scheme (ETS) cannot provide sufficiently high carbon prices to foster the development of renewable energy technologies. Blanco and Rodrigues (2008) calculate a minimum carbon price of at least EU€ 40 per tonne of CO_2 to maintain the incentive level of financial support policies for wind power in Europe. They argue that carbon prices only reflect the beneficial impact of wind power on climate change mitigation and fail to clarify its contribution to the security of supply or job creation. Wittmann (2013) and Sorrell, Harrison, Radov, Klevnas, and Foss (2009) provide an in-depth theoretical (and graphical) analysis on the correlation of white certificate schemes and the EU ETS. Grubb et al. (2015) compare 89 scenarios from 12 models of China's CO_2 emissions and articulate the further need of considering more realistic macroeconomic assumptions in these models. However, there are only a few studies that focus on the linkage among climate targets. For example, Zhang and Bauer (2013) assess the target coherency between China's 2020 energy intensity target and its 2020 renewable energy target. To our knowledge, there is so far no study that demonstrates the linkage of the newly announced 2030 climate targets in China.

Regarding analysis of the linkages among climate targets, one option is to use complex computer programs that integrate thousands of variables and equations. Although these models certainly provide references and insights for policy-making and public debate, non-modellers often consider them to be 'black boxes' and therefore these models cannot always provide precise information to inform political discussions in terms of causality. For an extreme example, see Pindyck (2013), who argues that analyses of climate policy based on integrated assessment models create an illusory and misleading perception of knowledge. In such a context, simple but robust interpretation can provide a complementary reference for a better understanding of the consequences of emissions trajectories, which could enhance international climate change negotiations and facilitate domestic climate policy implementation.

This article uses a simple method and aims to interpret two linkages between China's 2030 climate targets: first, the implication of the achievement of China's 2030 non-fossil fuel energy target to China's carbon emissions peak, and second, possible combinations of a simultaneous achievement of non-fossil fuel energy target and carbon intensity target facing the uncertainty of GDP growth and energy elasticity. The article is organized as follows: Section 2 describes the method used, Section 3 presents the data obtained, while results and conclusions are discussed in Sections 4 and 5, respectively.

2. Methods

Calculations were carried out based on the following:

(1) The achievement of China's non-fossil fuel energy targets[2] was used as the starting point of the analysis for time horizons of 2020 and 2030. It is assumed that China will achieve its non-fossil fuel energy targets by 2030 (further explanation in next paragraph).
(2) The anticipated consumption of each non-fossil fuel energy source by 2020 and 2030 was obtained from several official plans and studies from Chinese think-tanks. It was assumed that anticipated targets will be met.
(3) These non-fossil fuel consumption figures were added together to obtain the total non-fossil fuel consumption by 2020 and 2030. Total primary energy demand (TPED) could then be obtained by dividing total non-fossil fuel consumption by the planned targets (15% and 20% respectively for 2020 and 2030).
(4) The proportions (in percentage form) of coal, oil and natural gas in the TPED were obtained from related official documents (NDRC, 2014) and selected studies from official think tanks. Adjustments were made based on rational fossil fuel energy mix scenarios for the periods until 2020 and 2030 (see Section 3 below).
(5) Total CO_2 emissions by 2020 and 2030 can be calculated using the CO_2 emissions factors of different fossil fuels.
(6) A (real) GDP growth rate was assumed to enable the calculation of carbon intensity per GDP (thereafter named as carbon intensity) and total primary energy consumption elasticity to GDP. We also define carbon intensity as per GDP CO_2 emissions in the following text.

The assumption that China will achieve its non-fossil fuel energy targets (the starting point for this analysis) is based on several factors. First, China in general achieves its announced targets, in particular those issued to the international community. For example, China announced its intention to reduce its GDP energy intensity by 20% by 2010 relative to 2005 level, managing to obtain a 19.1% reduction by the end of 2010. Second, central and local Chinese governments promote the development of non-fossil fuels with concrete supportive measures. For example, China has set a target of increasing installed solar power capacity by 10 GW each year (State Council of China, 2013). This target was achieved in 2014 (total new installed solar power capacity was 10.6 GW[3]) and the Chinese government remains optimistic on the achievement of the target in 2015[4].

3. Data and scenario design

Specific non-fossil fuel targets measured in absolute amounts by fuel type are summarized in Table 1. The expectations for 2020 are obtained from the NDRC (2014), which is the planning authority responsible for energy development in China, and therefore can be regarded as government planning data. Estimates for 2030 were extracted from the latest findings by China's government-affiliated research institute, the China National Renewable Energy Center[5], which is a major official think-tank that focuses on China's renewable energy development[6]. These figures are based on the judgements of

Table 1 Likely scenario of non-fossil fuel capacity (GW) in 2020 and 2030

	Hydro	Nuclear	Wind	Solar	Biomass
2010	213	10	31	0.3	7
2014	302	20	96.4	28	11
2020 (government planning)	350	58	200	100	30
2030 (envisioned)	350	80	400	400	30
Annual running hours	3500	7000	2000	1500	3000

Source: Historic data is obtained from the flash report of China electricity council (CEC), China.

experts, as public policy decisions are still highly reliable on experts' judgement today in China. Undoubtedly, these data may be an underestimation or an overestimation of the development capacity of non-fossil fuels, thus affecting results such as China's carbon emission peak level. However, the intention of this article is to provide a demonstration on the linkage of climate targets, not the relevance and methodologies of projections (which have been done by many other studies). The relevance of projected 2030 data is not a central issue here (although it is a very important topic) and does not affect major findings in this article. Finally, annual running hours for primary energy are based on industrial experience and applied both for 2020 and 2030.

Table 2 summarizes existing targets for the primary energy share announced for 2020 in China. As seen, if the percentages of coal (62%), gas (10%) and non-fossil fuels (15%) are added together, this leaves crude oil with only a 13% share of the TPED by 2020 in China. Given that the current share of crude oil in the TPED is around 18–19%, this 13% target could be very hard to achieve, as it would necessitate a major reduction in the consumption of oil products in China, a reduction that would be very difficult considering the rapidly expanding transport sector, which is the major consumer of oil products. Such incongruity may be explained by the fact that different authorities are in charge of setting different energy targets in China and there may be a lack of coordination between them.

We designed a positive scenario (Table 3) that corresponds to a very significant decrease in the coal share of the TPED. Recent data (2014) indicate that the share of coal in China's TPED has decreased

Table 2 Existing energy targets in China: 2020

Primary energy type	Targets as share of TPED	Nature of the target	Source
Non-fossil fuel	15%	Compulsory	The 12th Five Year Plan of China
Natural gas	10%	Indicative	NDRC (2014)
Coal	62%	Indicative	NDRC (2014)
Oil	13%		Calculated.
Total	100%		

Table 3 Scenario design: energy mix 2020–2030

Energy Mix	2005	2010	2020	2030
Coal	71%	68%	58%	50%
Oil	19.8%	19.0%	17.0%[b]	18.0%[b]
Gas	3%	4%	10%[c]	12%[a]
Non-fossil fuels (for electricity generation)	7%	9%	15%	20%
Non-fossil fuels (non-electricity fuel) (unit: 10^8 tce)	0.1	0.3	1	1.5
TPED with consideration of non-electricity non-fossil fuels (unit: 10^8 tce)	23.6	32.5	51.1	52.9

Note: Historical data obtained from NBS. Non-fossil fuels share assumes that targets (2020–2030) are achieved. tce: tons of coal equivalent. Other sources: [a]envisioned target; [b]residual amount after subtracting other targets (own calculation); [c]NDRC (2014).

slightly (Myllyvirta, 2015). Calculations in this article are based on the assumption that the share of coal will decrease by 1% per year until 2030 from its 2014 level of 66%. The share of gas by 2020 and 2030 is obtained from official sources and the share of oil is assumed to be the remaining percentage once official targets for the other energy sources have been subtracted: 100% minus the share of coal, gas and non-fossil energies. It should be noted that China's 2020 and 2030 non-fossil fuel targets include both electricity and non-electricity uses of non-fossil fuels (as seen in Table 3). It should also be noted that the figure of 12% for the proportion of gas in the total energy mix by 2030 could be considered as a conservative estimate. A higher share of gas corresponds to a lower share of coal in the energy mix, thus contributing to lower total CO_2 emissions. Figures for annual running hours are based on technological constraints in industrial electricity generation.

Finally, GDP growth rates of 8% and 6% (see OECD, 2012) are assumed respectively for the periods 2005–2020 and 2020–2030 to reflect a relatively rapid rate of economic development in China prior to 2020, followed by a period of slightly slower growth for 2020–2030.

4. Results

4.1. Total carbon emissions

Table 4 shows the total CO_2 emission from fossil fuel combustion in 2020 and 2030, along with related data required to carry out the calculations described in Section 2. As shown, total CO_2 emission derived

Table 4 CO_2 emission and related data

	2005	2010	2020	2030
Annual TPED growth from 2005 (%)		7	4	2.6
Total CO_2 emission (Gt)	6.3	8.4	9.7	8.6
CO_2 emissions growth rate (%)		5.7	2.9	1.2

Source: CO_2 emissions in 2005 and 2010 are obtained from BP. Growth rate is relative to the 2005 base year.

from energy consumption is likely to peak somewhere between 2020 and 2030: total CO_2 emission is likely to reach 9.7 Gt in 2020 and 8.6 Gt in 2030. The annual growth rates of total CO_2 emission relative to 2005 are 2.9% and 1.2% for 2020 and 2030, respectively, in comparison to 5.7% for the period 2005–2010.

In terms of China's total national CO_2 emission, this article does not account for CO_2 emission arising from industrial processes because the data is limited in this regard. According to the Second National Communication on Climate Change of China[7], CO_2 emission from industrial processes represent roughly 10% of the total CO_2 emission from energy activities in 2005. Even if this percentage remains unchanged, it would not have a significant effect on the total CO_2 emission peak obtained using the method applied in this article. Furthermore, it is very likely that CO_2 emission from industrial processes will decrease in future as a result of: (1), improvements in production technologies and efficiency; (2), the elimination of small and inefficient industrial installations; and (3), a more limited expansion of the property market and infrastructure in the coming years (even though China will continue to invest in infrastructure for the purpose of improving citizen well-being), which are major consumers of cement and steel, the latter being the main source of CO_2 emission from industrial processes. This could imply a total CO_2 emission peak prior to 2030.

4.2. Uncertainty

Our method predominately rests on the assumption that there will be a change in the coal share of the TPED. This is based on the actual Chinese situation: there will be a growing need for oil to meet the increasing demand for transportation, while the use of natural gas will also increase as it is a good substitute for coal, particularly for heating as it enables a reduction in the level of local air pollution.

To examine the impact of the percentage of coal on CO_2 emission up to 2030, Figure 1 shows the development of CO_2 emission derived from fossil fuel combustion according to the scenario described above, together with two additional scenarios that are set out in Table 5. The first scenario is based on governmental planning data (NDRC, 2014) for 2020, which is then extrapolated for the period up to 2030, assuming a slight decrease in the coal share compared with the period until 2020. It was assumed that there will be an increasing marginal cost to the reduction of the coal share. The second scenario was used to analyse the effects of a constant coal share over the period 2014–2030, a situation that is very unlikely because China will continue in its efforts to reduce coal consumption. It must be noted that these two additional scenarios are very unlikely to happen as China aims to reduce the share of coal. The objective is to show the implication of the achievement of non-fossil fuel target to the time of China's carbon emissions peak. As shown, under all three scenarios based on different coal share assumptions, the CO_2 emission (fossil fuel combustion) peak could be attained somewhere between 2020 and 2030. This is due to the fact that the increase of the share of non-fossil fuels significantly lowers the carbon intensity of energy use, thus enabling China to achieve its energy-related carbon emissions peak before 2030.

4.3. Energy demand elasticity

Table 6 shows energy demand–GDP elasticity. Our calculations (Section 4.1) imply a reduction of the energy demand elasticity to 0.52 (as an average for 2010–2020) and then 0.43 (average for 2020–2030).

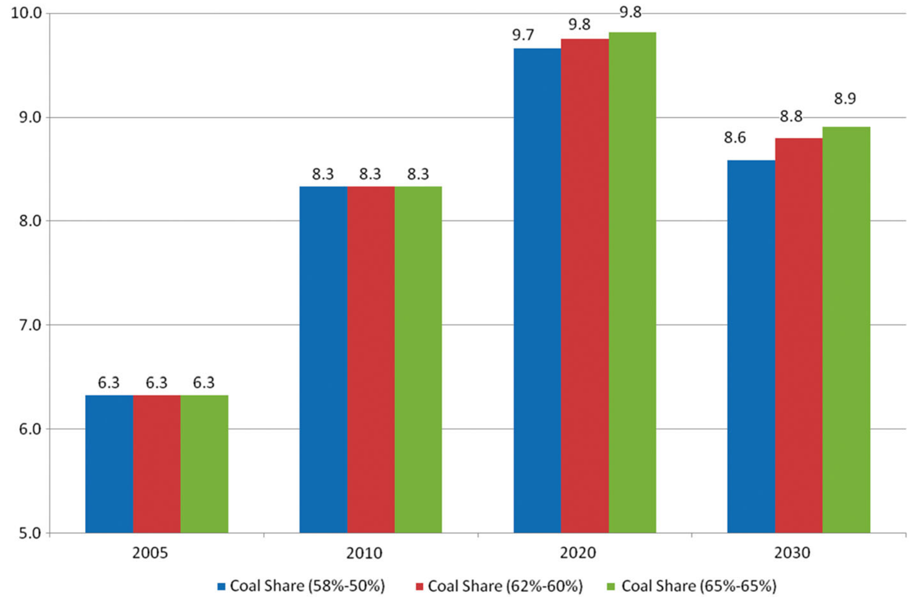

Figure 1 Impact of coal share uncertainty on CO_2 emissions

Table 5 Energy mix of two additional scenarios

Coal 2020	Coal 2030	Non-fossil fuels 2020	Non-fossil fuels 2030	Gas and oil 2020	Gas and oil 2030
62%	60%	15%	20%	23%	20%
65%	65%	15%	20%	20%	15%

Source: Authors' own assumption.

Table 6 Energy consumption GDP elasticity

1990–1980	2000–1990	2010–2000	2020–2010	2030–2020
0.44	0.28	0.72	0.52	0.43

Note: 1980–2010 data are calculated based on the NBS database with GDP index of 1978=100. 2020–2030 data are based on the authors' own calculations.

In other words, this means that for China to achieve the results presented in Section 4.1, an acceleration of the decoupling of GDP growth and energy demand until 2030 would be required: energy demand elasticity for the period of 2020–2030 would have to be brought back to its level during China's early stages of economic reform (1980–1990).

Table 7 Energy sector and per GDP carbon intensity

	2010	2020	2030
Energy carbon intensity decline (relative to 2005)	5%	20%	30%
Annualized energy carbon intensity decline rate	− 0.9%	− 1.44%	− 1.42%
GDP carbon intensity decline (relative to 2005)	− 24.8%	− 56.8%	− 71.7%
Annualized carbon intensity of GDP decline	− 5.5%	− 5.4%	− 4.9%

Several factors suggest that is possible to achieve this requirement. First, as Figure 2 shows, in recent years, energy demand elasticities are at or even below such levels (e.g. 0.41 for 2008–2007). Second, China's ongoing reforms aim to restructure its economy towards a higher share of high value-added and technology-rich products. The promotion of the development of service and high-end manufacturing sectors (which are in general less energy/carbon intensive) are very likely to ensure such a decoupling, together with the improvement of energy efficiency. Third, in comparison to the 1980–2000 period (Table 6), energy demand elasticity is much higher in the 2000–2010 period. One explanation for this change is the rapid expansion of energy-intensive sectors between 2003 and 2005 (Liao, Fan, & Wei, 2007). As shown in Figure 2, annual energy demand elasticity reached a very high level (1.6) during this period. A number of government efforts have led to a lowering of the energy demand elasticity (Liao et al., 2007): elasticity fell continuously from 1.6 in 2004 to 0.41 in 2008 (together with the impact of international economic crisis), before slightly rebounding in 2009. Based on this past experience, it is conceivable that China is capable of ensuring that energy demand elasticity falls in line with the necessary requirements for achieving the carbon emissions trajectory described in Section 4.1.

It should be emphasized that the very low average energy demand elasticity during the period of 1990–2000 is very probably due to the declining quality of energy statistics since the mid-1990s in China (Sinton, 2001). This implies that the real energy demand elasticity could be higher during this period.

Energy demand elasticity can be further combined with GDP growth rate to assess the achievement of the 2030 non-fossil fuel target. The downward curve in Figure 3 indicates the relation between GDP

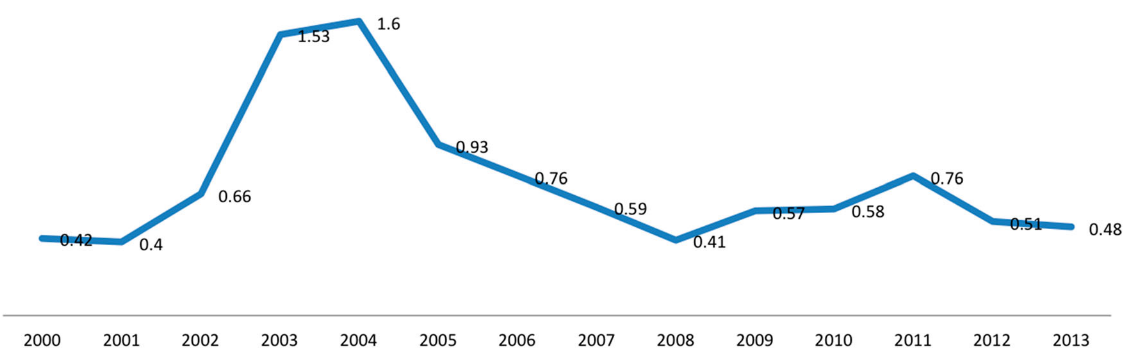

Figure 2 Annual energy consumption elasticity 2000–2013

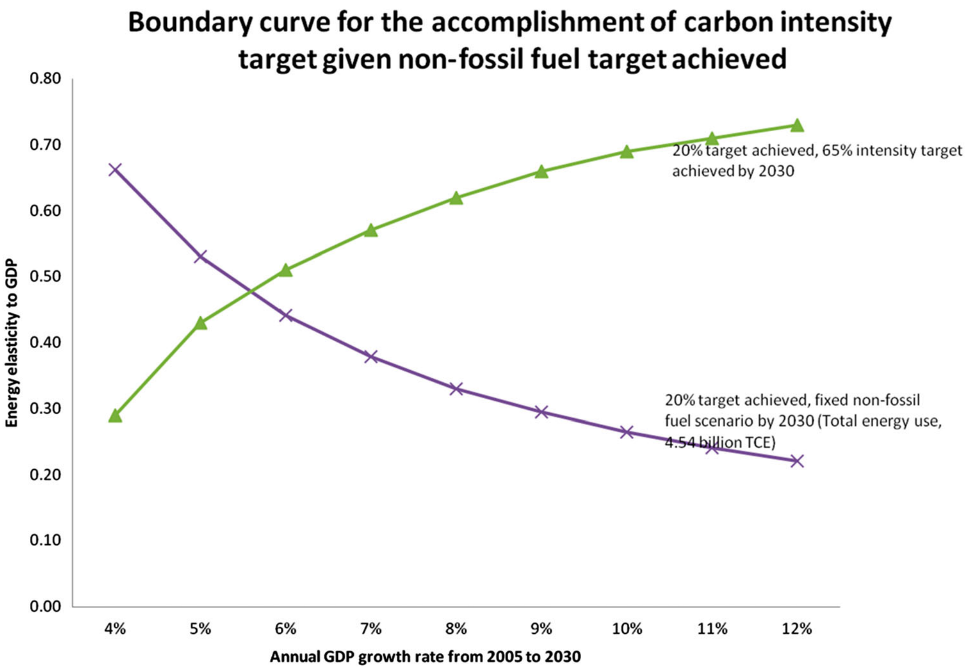

Figure 3 Boundary curve for the accomplishment of carbon intensity targets given non-fossil fuel target achieved

growth rate (*x* axis) and the energy demand GDP elasticity (*y* axis) in order to achieve the non-fossil fuels target (20%) by 2030 with a fixed absolute amount of non-fossil fuel consumption (or total energy consumption). This is based on equation 5 from Zhang and Bauer (2013), using the carbon intensity change obtained under the scenario described above. Combinations below the curve will lead to over-achievement, while combinations above the curve indicate under-achievement of the target. In general, a higher GDP growth rate corresponds to a lower energy consumption elasticity to achieve the same non-fossil fuel target. While a lower GDP growth rate (which will probably be the case in the coming decade) corresponds to a lower relative decoupling of energy use from GDP to achieve the non-fossil fuels target by 2030.

4.4. Carbon intensity

Compared with China's 2020 target that aims at a 40–45% reduction in carbon intensity relative to 2005, the scenario assessed in this article would induce a carbon intensity reduction of 56.8% by 2020 (Table 7), which is higher than the official target. Furthermore, the carbon intensity by 2030 obtained using the method set out in this article is 71.7% (relative to 2005), which is higher than the target set in China's INDC (60–65%). This indicates that China will be able to reduce its carbon intensity by more than the amount required by its INDC targets, providing that it is able to achieve the 20% target for absolute non-fossil fuels consumption by 2030, which we assume will be the case in the 'accounting' approach applied in this paper.

If we consider this carbon intensity level (71.7%) to be a given, we obtain annual carbon intensity reduction rates of 5.4% and 4.9% for 2010–2020 and 2020–2030 respectively. The 5.5% annual reduction rate of carbon intensity for 2005–2010 corresponds to an increasing marginal abatement cost in future. Under the scenario described in this article, despite a decrease in the reduction of carbon intensity, the carbon intensity of China's energy sector (carbon emissions per unit of energy use) is reduced by 20% and 30% by 2020 and 2030 respectively, due to substitution effects between non-fossil and fossil fuels, and also between different types of fossil fuels. This results in an annual reduction rate of energy sector carbon intensity of 1.4% for the period of 2010–2030, which is higher than the rate (0.9%) during the period 2005–2010.

4.5. Coherency among targets

Assuming the 2030 target of 20% non-fossil fuels is achieved simultaneously with the per GDP carbon intensity target (i.e. 65%) given in China's INDC, according to equation 5 in Zhang and Bauer (2013) we can obtain an upward curve, shown in Figure 3, which indicates the GDP growth rate and energy elasticity corresponding to the achievement of both non-fossil fuel and carbon intensity targets by 2030, while with different amount of total non-fossil fuels consumption for each set of GDP growth and energy elasticity, by 2030. On this curve, the lower level indicates lower TPED. The region above the curve corresponds to a failure to meet the 2030 carbon intensity target, and the region below to achievement beyond the target. The two curves in Figure 3 can be used to assess various combinations of GDP growth rate and energy elasticity: if the corresponding point on the graph falls above both curves, this indicates that neither the non-fossil fuel share nor the carbon intensity targets set out in China's INDC would be attained; a point on the right side of the two curves indicates failure to meet the non-fossil fuel share target but that the carbon intensity target would be exceeded; any point below both curves indicates that both targets would be exceeded; while any point on the left side of the two curves indicates that the non-fossil fuel share target would be exceeded, but the carbon intensity target would not be met.

The intersection of the two curves in Figure 3 corresponds to the achievement of the non-fossil fuel share and carbon intensity targets in the INDC with a TPED level identical to the scenario assessed in this article through the application of an 'accounting' approach, with an average annual GDP growth rate (2005–2030) and energy elasticity of 5.9% and 0.48, respectively. The scenario presented above results in an annual GDP growth and energy elasticity as 6.2% and 0.43, respectively, figures that are positioned on the downward curve in Figure 3, but slightly below the upward curve. Certainly, a carbon intensity target helps to calculate total CO_2 emissions with real/anticipated GDP growth. However, carbon intensity target setting may be inconsistent with non-fossil fuel development in China. As shown in this article, carbon intensity depends on the progress towards the achievement of the non-fossil fuels target by 2030. In consequence, the energy intensity target becomes necessary to control TPED, and to control total CO_2 emissions together with non-fossil fuel targets in a coherent manner.

5. Conclusions

This article describes the application of a simple method which, through the use of official data, enables the demonstration of linkages between China's 2030 climate targets. First, it points out that China's success in terms of achieving its 2030 non-fossil fuel target will affect its carbon emissions peak prior to 2030, regardless the assumption of energy mix. Second, it shows how non-fossil fuel and carbon intensity targets can be achieved simultaneously based on different assumptions of GDP growth rate and energy consumption elasticity. It further points out that a GDP carbon intensity target does help to control the absolute level of a carbon emissions peak, but could be inconsistent with the development of non-fossil fuel power.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes

1. https://www.whitehouse.gov/the-press-office/2014/11/11/us-china-joint-announcement-climate-change.
2. China has set a target of 15% and 20% non-fossil fuel energy in the total primary energy demand (TPED) by 2020 and 2030 respectively. The former (15%) is one of China's 2020 pledges to the UNFCCC and the latter, being the only quantitative target (20%), is written into the US–China Joint Announcement on Climate Change issued in November 2014.
3. Source: National Energy Administration of China (http://www.ccchina.gov.cn/Detail.aspx?newsId=51049&TId=57; in Chinese).
4. See communication of the Ministry of Industry and Information Technology of China, available at http://www.miit.gov.cn/n11293472/n11293832/n11294132/n12858462/16793668.html (in Chinese).
5. http://www.cnrec.org.cn (in Chinese).
6. In China, nuclear power is classified as a renewable energy.
7. http://www.ccchina.gov.cn/archiver/ccchinaen/UpFile/Files/Default/20130218145208096785.pdf.

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