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Prospect of China's energy conservation and emission reduction during the remaining years of the 12th Five-Year Plan period

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Abstract: China has set controlling greenhouse gas (GHG) emissions as a key task and an essential part of economic development and industrial upgrading for energy saving and climate change mitigation. Energy conservation has been given great attention since the beginning of the 11th Five-Year Plan (FYP) period (2006-2010), and in 2011, specific goals have been made for reduction of energy intensity and carbon intensity for the 12th FYP period (2011-2015). In this study, according to the regional data of the first two years of the 12th FYP period, current situations of energy conservation and emission reduction in China and its provinces were analyzed. Recommendations for 2013-2015 are discussed based on continuing goals, economic and natural conditions. Shifting of energy consuming structure is primarily discussed as one of the main approaches, and alternate methods of energy restructure are suggested due to the limitation of natural resources in China.

Keywords: Carbon intensity, China, Emission reduction, Energy conservation, Energy intensity, Five-Year Plan

1 Introduction

During the last several decades, climate change and global warming has gradually become a problem internationally. In order to avoid the disastrous consequences for human beings, gradually decreasing greenhouse gas emission to decelerate global climate change has been given great consideration. Many developed countries have made significant efforts on emission reduction after signing the Kyoto protocol. Although the Kyoto protocol does not include mandatory requirement for developing countries, being the largest energy consumer and CO_2 emitter in the world, China has great influence on global climate change mitigation.

China has addressed climate change issues into its national long-term plans. In the 11th Five-Year Plan (FYP) period (2006-2010), Chinese government made clear goals on energy conservation. By the end of

2010, China had achieved most national and provincial goals. The accumulated decreasing rates of energy intensity (energy consumption per GDP) were 19.1% at national level and ranged from 15% to 20% at provincial level. Subsequently, in 2011, the Work Plan for Controlling Greenhouse Gas Emissions was issued for the 12th FYP Period (2011-2015). China had proposed the objectives not only on decreasing energy intensity but also on reducing carbon intensity (CO_2 emission per GDP). The specific goals of national and provincial energy intensity is 16% and 10% to 18% accumulated decrease (by 2015 compared with 2010), respectively, on the basis of differences on industrial conditions, economic growth modes, and natural environments (NDRCC, 2012). On the aspect of carbon intensity, the national decreasing target and provincial decreasing targets are 10% to 19.5% (by 2015 compared with 2010). In addition, in order to change the situation of high carbon emissions more thoroughly, China plans to raise the proportion of non-fossil energy consumption in the total primary energy consumption to 11.4% during the 12th FYP (Wang et al., 2013; Guan et al., 2014).

Energy intensity was decreased rapidly during the 11th FYP period. However, the economic situation change increases the difficulty of energy conservation and emission reduction in the 12th FYP period. According to the data in 2011-2012, the decreasing rate of energy intensity and carbon intensity are relatively slow for achieving the target by the end of 12th five-year period. The factors which restrict China's continuous decrease of energy intensity and carbon intensity include natural conditions of oil and gas shortage, the structure of energy consuming, which mostly depends on coal, and the rapid increase of energy demand led by economic. The analysis on available data of 2011-2012 indicated great pressure of energy conservation and emission reduction for the remaining years of the 12th FYP period.

Through the analysis of economic situations, energy consumption and carbon emission in the period of 2005-2012 at both national level and provincial level, great challenge in energy conservation and emission reduction in the period of 2013-2015 can be found. In the view of the serious situation, more effort need to be made in transforming both industry structure and energy consumption structure to achieve the energy intensity target and carbon intensity target of the 12th FYP. In this study, performance of energy conservation and emission reduction was evaluated in the 11th FYP period and the first two years of the 12th FYP period. The challenge for the next stage is discussed and the feasibility for accomplishing the target is analyzed in the view of adjusting energy consumption structure.

At present, 11.5% of the global primary energy consumption is consumed in China (WD, 2012). Among the large amount of energy consumption, 67% are coal consumption. In addition, low utilization efficiency and high emission per unit energy consumption are properties of coal and thus relying on coal keeps energy intensity and carbon intensity of China's industry at high levels. To decrease the negative effect of coal consumption, China expects to alternatively improve the structure of energy consumption and switch from high-carbon utilization to low-carbon coal utilization (Shen and Zhao, 2010). This paper also analyzed the present situation and developing potential of restructuring energy consumption and applying low-carbon technology. In the end, aiming at the accomplishment of the targets in the 12th FYP, current situations are presented and the statuses of the transformation of energy consumption are revealed in China's 30 provinces.

2 Data and calculations

In this paper, data were obtained from the China Energy Statistical Year Book (2006-2013) and the energy conservation and emission reduction reports issued by the central and provincial governments, to calculate and analyze the energy saving progress of China's 11th and 12th FYP periods. The national energy consumption data were directly obtained from the national primary energy consumption in the energy

balance sheets of China. Provincial energy consumption data were calculated by multiplying all types of physical quantities of primary energy consumptions and their corresponding coal equivalent factors for each province. The coal equivalent factor for each type of energy resources was obtained from China Energy Statistical Year Book (2013). In addition, carbon emissions were calculated by using emission factors and energy consumptions as below.

Total energy consumption:

$$E_{total} = E_{coal} + E_{oil} + E_{gas} + E_{non\text{-}fossil} \quad (1)$$

Total carbon emissions:

$$C_{total} = C_{coal} + C_{oil} + C_{gas} + C_{non\text{-}fossil} = E_{coal} \cdot \theta_{coal} + E_{oil} \cdot \theta_{oil} + E_{gas} \cdot \theta_{gas} + E_{non\text{-}fossil} \cdot \theta_{non\text{-}fossil} \quad (2)$$

In the equations above, E is energy consumptions of coal, oil, gas and non-fossil energy. C indicates carbon dioxide emission from coal, oil, gas and non-fossil energy. C is calculated by multiplying consumption quantities E and carbon emission factors θ. Referring to the published data from National Development and Reform Commission, emission factors are 2.64, 2.08 and 1.63 tCO2/t coal equivalent (tce) for coal, oil, gas respectively. The data of carbon emissions from non-fossil energy was not available in China. The carbon emission factors for non-fossil energy were assumed to be 0 as it is primarily constituted by nuclear power and renewable power such as solar power, hydropower, and wind power. The energy intensity and carbon intensity were calculated as below.

Energy intensity = E_{total} / GDP (3)

Carbon intensity = C_{total} / GDP (4)

In this paper all energy consumptions were calculated in ten thousand tce. Carbon emissions were calculated in ten thousand tonnes of carbon dioxide (tCO_2). GDP were displayed in hundred million Chinese Yuan (CNY) in the price of 2005.

3 Energy intensity and carbon intensity

The decreasing rates of both energy intensity and carbon intensity slowed down in 2011-2012 compared with the 11th FYP period, which made it a very challenging task for the following years in the 12th FYP period. Table 1 shows national energy intensity and national carbon intensity from 2005 to 2013. Table 2 displays the accomplished targets during the 11th FYP and the first 2 years of 12th FYP, and the unachieved targets for 2013-2015.

[Insert Tables 1 and 2 here]

The energy intensity decreased rapidly in the 11th FYP period (by 4.14% annually). However, in the first two years of the 12th FYP period, the decreasing rate dropped to 2.93% per year, which brought large pressure on the following three years. In order to accomplish the targets of the 12th FYP, the annual decreasing rate needs to be at least 3.8% per year during 2013-2015. The goal is achievable referring to to the historical effort in 2006-2010 (4.14% annual decrease), but challenging due to the current situation. According to the estimation by Chinese government, the decreasing rate of national energy intensity rose to 3.7% in 2013 (NBS, 2014). In long-term perspective, by the average annual decreasing speed in the 11th FYP period, 15-year accumulated rate would decrease to 45.6% (2020 compared with 2005). However, by the decreasing speed in the first two years in the 12th FYP, the accumulated rate would be only 39.9%. If

the decreasing rate could be maintained as in 2013, the 15-year accumulation would return to 44.1%. Figure 1 shows the predicted tendency of the reductions of energy intensity in the above decreasing speed scenarios.

[Insert Figure 1 here]

On the other hand, the international commitment made by Chinese government was to decrease carbon intensity by 40%-45% by 2020 compared with the level of 2005. Nevertheless, the control of carbon intensity had not been put into effect until the beginning of the 12th FYP period. The decreasing target of carbon intensity of the 12th FYP is 17% compared with the level of 2010, and thus the average expected annual decreasing speed is 3.4%. Whereas, in 2011 and 2012, accomplished annual decreasing rate was only 2.07%. As a result, a 4.7% annual decrease is the bottom line for the following three years (2013-2015).

The decreasing targets of energy intensity for China's provinces are 10%-18% (SCC, 2011), as shown in Table 3. Decreasing rate around 4% for a single year can be considered as very fast speed according to the progress in the 11th FYP period. Therefore, provinces with targeted annual decreasing rate for more than 3.5% in 2013-2015 shall make great efforts. Moreover, by the end of 2012, normally 40% of the target should have been completed in each province. Figure 2 displays a visualized view of the ratio of accomplished and unaccomplished targets of 30 provinces. During the first two years of the 12th FYP period, 11 provinces have completed more than 40% of their targets. These provinces (Beijing, Tianjin, Hebei, Jilin, Shanghai, Fujian, Jiangxi, Henan, Hunan, Chongqing and Sichuan) are more likely to achieve their goals of the 12th FYP on schedule eventually. On the contrary, four provinces are facing serious situations. Xinjiang, Ningxia, Qinghai and Hainan showed increases in energy intensity in 2010-2012. Particularly, increases in Xinjiang and Qinghai are as high as 16.1% and 9.8% respectively, which make it difficult to reach their targets of the 12th FYP. The other 15 provinces reached 30%-40% of their targets during 2011-2012. Namely, half of the provinces need to step up the pace. In general, fast progresses tend to be taken in provinces with large population and well economic development situation. Whereas, sparsely populated western provinces with lower economic growth are likely to accomplish their targets with great difficulties.

[Insert Table 3 and Figure 2 here]

The progresses of carbon intensity reduction are reported in Table 4, which shows the changing processes during 2005-2012 and the expected annual decreasing rate for 2013-2015. The unaccomplished annual targets for different provinces ranged from 1.64% to11.59%, which indicates large differences in accomplishments during 2011-2012. As shown in Figure 2, eleven provinces achieved accumulated completion higher than 40%, in which eight of them reached the rate higher than 60%. However, situations in other eleven provinces are not optimistic. These provinces left more than 60% of their targets for the remaining three years of the 12th FYP period. Moreover, increases of carbon intensity occurred in seven provinces. In Hainan, Inner Mongolia, Heilongjiang, Qinghai, Gansu, Ningxia and Xinjiang, carbon intensity continuously increased since the beginning of the 11th FYP period.

[Insert Table 4 and Figure 3 here]

Comparing Figure 2 with Figure 3, it is obviously that current challenges on controlling carbon intensity

are more severe than controlling energy intensity for most of the provinces. For many provinces, control of carbon emission has even not begun. At national average level, annual decreasing rate higher than 5% can be considered as very fast speed. Thus the unaccomplished targets for 2013-2015 are challenging in thirteen provinces. In addition to the 7 provinces that have increasing carbon intensity during 2011-2012, Hebei, Jiangsu, Anhui, Fujian, Guangxi should also speed up their decreasing speed largely.

4 National and provincial challenges and improving approaches

4.1 Current challenge in the 12th FYP period

The current progress of energy saving and emission reduction hardly meet the goal of the 12th FYP for either the decelerated decreasing energy intensity or the accelerated decreasing carbon intensity. Especially the control of carbon intensity is facing serious situation. During 2011 and 2012, the decreasing rate of carbon intensity is far from the target. Therefore, greater efforts should be made to decrease carbon intensity from 2013 to 2015.

The decrease of energy intensity reached 19.1% in the 11th FYP period. Although the decreasing speed declined to 2.93% per year in the first two years of 12th FYP period, current decreasing rate can make accumulate decrease to 40% (compared with 2005) by the end of the 13th FYP (2016-2020). However, such rate cannot meet the specific requirement of the 12th FYP, in which 3.80% is the bottom line of annual decreasing rate for 2013-2015. According to past performance in the 11th FYP period, China is capable to obtain this speed in the 12th FYP period. Recent government bulletin shows that the estimated decrease of energy intensity in 2013 return to 3.7%. In general, the current control of energy intensity not only efficiently restricts the growth of total energy consumption but also guarantees a stability increase in economics.

China has made the international commitments to decrease carbon intensity by 40%-45% (compared with 2005) by 2020. The control of carbon intensity began to be put into practice since the beginning of the 12th FYP period. However, the current decreasing rate is too low to reach the long term goal of 2020. In order to achieve the long term goal methodically, the government set the short term goal of 12th FYP as 17% decrease. This requires a 4.7% annual decrease of 2013-2015 at the national level. Such rate is very challenging as it was only 2.07% during 2011-2012. Therefore, China still needs to make a great effort towards carbon intensity reduction.

4.2 Restructuring energy consumption is an important way for carbon emission control

In order to fundamentally slow climate change, China has to decrease both the carbon dioxide emissions and carbon intensity. However, along with increasing GDP and energy demand, the increase of carbon dioxide emissions is difficult to be avoided in short term. One feasible solution is to control the unit carbon dioxide emissions. In other words, replacing high carbon energy with low carbon energy is the long-term approach. Precedents took place in Europe. From 1990 to 2007, Germany decreased carbon intensity and carbon emission by 48% and 15% respectively through increasing the proportion of natural gas and renewable resources (OECD, 2010). The UK decreased carbon emissions by 21% by decreasing the proportion of coal from 1990 to 2012 (NAEI, 2013). Therefore, gradually decreasing the proportion of coal and oil is an experience China can learn from. In the 12th FYP period, the goal of non-fossil energy proportion is 11.4%. Achieving this challenging target largely depends on restructuring both energy consumption and economical structure. The direct method is to reduce high carbon energies such as coal and oil. The indirect method is to reduce high energy-consuming industry.

4.2.1 Energy restructure is in slow progress

The large cardinal proportion of coal and the increasing energy demand are restrictions to energy restructuring. With relatively low reserve of oil, natural gas and renewable energy sources, China has been relying on coal for a long history. Although the proportion of coal had decreased by 10% from 1990 to 2012, current proportion of 66.6% is still an exceedingly large number compared with other countries. Moreover, the total energy consumption in 2012 is almost four times of that in 1990. The change occurred slowly and strenuously on the premise of energy supply. According to Table 5, details of energy restructure are revealed as follows:

- The proportion of coal was basically unchanged in the 11th FYP period and only decreased by 1.4% in the first two years of the 12th FYP period;
- The proportion of oil is decreasing continuously but slightly. The accumulate decrease is only 1% since 2005;
- Natural gas has increased for a large amount since 2005. However, it is hard to make a difference for energy structure due to the small cardinal proportion;
- The increase of renewable resource is slow and unstable.

[Insert Table 5 here]

Although the carbon intensity is decreasing by 2% annually, the carbon dioxide emission is increasing in a faster rate. In general, the methods which were successfully used by other countries seem to be less practical for China. The reformation of energy structure of China cannot simply decrease the proportion of fossil fuel.

4.2.2 Low-carbon technique and renewable energy are the paths for long term

Energy supply structure highly depends on local energy distribution. Due to the reasons discussed above, forcibly changing the energy structure is not appropriate for China. Better solutions are switching from high-carbon to low-carbon energy utilization and developing renewable resources.

(1) Low-carbon technique for high-carbon energy

- Improve coal efficiency

The coal consumption will not significantly decrease in the coming few years. The direct method to decrease the carbon emissions is to improve coal calorific efficiency. By 2012, 28% of the total energy was wasted in energy transformation in China (NBS, 2013). Particularly, the transformation energy lost by power stations was as high as 67%. Excluding the proportions from hydro-power stations, wind-power stations and nuclear-power stations, the lost percentage for thermal-power stations could be even higher. Nowadays, more than 78% of the electricity supply is provided by thermal-power stations in China, thus improving coal calorific efficiency is an urgent task.

- Substitute natural gas

The carbon dioxide emission factors for coal and natural gas are 2.64t/tce and 1.63t/tce respectively. Replacing coal by natural gas can efficiently lower the carbon emissions. Under the condition of abundant coal and scarce natural gas, synthetic natural gas technique can be an alternative. According to “natural gas development for the 12th five-year plan”, the substitute natural gas will increase to 15-18 billion cubic

meter by 2015. Nevertheless, this amount only takes up approximately 10% of the total natural gas consumption (146 billion cubic meters in 2012). Continue to develope substitute natural gas industry can help to solve the problem of energy structure in the long run.

- IGCC

Integrated Gasification Combined Cycle (IGCC) is a good solution for the emission problem of thermal-power stations. Technically, IGCC can improve the net power generation efficiency to 43%-45%. Meanwhile, the emission is only 10% of the emission of traditional technique (NEA, 2012). IGCC technique has been added into China's national medium and long-term plan for science and technology development since 2006. Since 2012, 12 IGCC power generation and integrated projects have been carried out in China and the first independently developed IGCC power station is under construction in Tianjin. In the long term, these clean thermal-power stations can help to decrease carbon emissions largely without forcibly change the energy resources.

(2) Renewable energy

China has large reserve of renewable energy, in which solar power and wind power have considerable development potential. However, the biggest problem of renewable source is its instability and distribution. In the eastern area, the development of renewable resource is restricted. The available option is to increase the proportion of renewable energy in the western area. In addition, biogas is an ideal replacement for unclean energy in rural area. Low-cost investment and easily accessible material make biogas easy to spread in China.

- Wind power and solar power

The burdens of decreasing carbon intensity are very heavy in the western provinces of China. The large land with sparse population makes it more expensive to develop other low-carbon techniques. However, renewable energy that is unstable in other area becomes more practical in western provinces. Renewable resources, e.g. wind power and solar power, are very unstable due to variable weather conditions in eastern provinces. Relatively stable weather conditions in western provinces provide favorable conditions for developing renewable energy. Take Xinjiang for instance, sunshine duration is 2500-3550 hours per year and total annual radiation reaches 5000~6400 MJ/m^2 (Liu et al, 2008). This makes it possible to follow the successful examples such Nevada, the U.S, where average annual sunshine duration is more than 3000 hours. Nevada's Renewable Portfolio Standard (RPS) is increasing the share of solar power. By 2025, 25% of the electricity will come from solar power. If similar strategies are developed in Xinjiang, the continued growth in carbon intensity will be controlled (EIA, 2013). Furthermore, wind power is also available in the western provinces. In Inner Mongolia and northern Gansu, wind power density is 200-300W/m^2 and the effective time is around 70% (CMA, 2011) which makes it a great potential of wind power generation. Whereas, though the development of wind power is rapid in recent years, the economic loss in wind power enterprises makes the prospect discouraging. Supportive policies may help to relieve the problem of huge economic investment in wind power development.

- Biogas

In rural area, burning of uncleansed resource hurts the environment. An inexpensive, easily accessible replacement is biogas. Biogas is a low carbon energy that reduces the carbon emissions largely. Each year, the biomass waste resources in China can produce biogas the same calorific value as 12 billion cubic meter of natural gas (Guo, 2011) which can largely improve the present situation of heavy polluting energy in rural areas. China has been driving the development of biogas industry since 2000. By the end of 2012, the

biogas coverage in rural area has reached up to 23% of the residents (Zhang, 2012). The 12th FYP continuously enlarge biogas coverage. If biogas could be more popularized, the energy structure in rural China will be well transformed into low-carbon status.

4.2 Prospective targets (2013-2015) and restructure of energy consumption at provincial level

4.3.1 Regional energy intensity

In general, progresses of decreasing energy intensity in China are under normal process. According to historical record, 3%-4% is the capable annual decreasing range for most Chinese provinces. Provinces with annual targets under 3% are likely to exceed the goals. On the contrary, it is difficult for provinces with annual targets over 4% to achieve their goals. Therefore, seven provinces that have remaining annual targets under 3% for 2013-2015 are likely to exceed their goals for the 12th FYP. Twenty provinces are having annual targets between 3%-4%. For these provinces, the targets are achievable but need to be push through. However, the other 3 provinces, Qinghai, Ningxia and Xinjiang, can hardly complete their targets. Decreasing more than 4% could be completed but not in these 3 provinces according to their historical data. The speed of energy intensity decrease may depend on how easy it is to change the structure of energy consumption. In economically well developed provinces, energy intensity is decreasing in faster speed because it is more flexible for them to adjust their industrial energy consumptions. In western provinces, industrial structures are lack of diversity, which makes the targets difficult and slow to complete. Table 6 briefly summarizes the prospect of energy intensity reduction targets for 30 provinces in China.

[Insert Table 6 here]

4.3.2 Regional carbon intensity

Carbon intensity tends to be more difficult to decrease. Two main approaches to decrease carbon intensity are improving energy efficiency and replacing high carbon energy, which requires technical improvement and takes a long time. According to the national average level, the capable annual decreasing range for carbon intensity is 3%-5%. At present, nine provinces are making great progress and less than 3% of their annual targets are unaccomplished for 2013-2015. Nine provinces are taking smaller progresses but the remaining targets are still achievable. The other twelve provinces are facing severe situations. Their goals are difficult to be completed by 2015. The progress of decreasing carbon intensity is more complicated. Unlike energy intensity, regional distribution and socio-economic development status are not direct acting factors to carbon intensity. Transformation of energy structure may be a more effective driving factor. Table 7 gives the summary of the prospect of annual decreasing targets of carbon intensity for 30 provinces in China.

[Insert Table 7 here]

4.3.3 Restructure of regional energy consumption

Although the control of carbon intensity and energy intensity has brought remarkable improvements on energy conservation, the essential problem of carbon emission can hardly be solved without changing energy consuming structure. In the short term, in order to achieve the international commitments by 2020, the proportion of coal consumption in total energy consumption needs to stop increasing. As shown in Table 8, the consumption of coal is under control in Beijing, Shanghai and Hainan, where the proportions of coal consumption decreased to less than 50%. Meanwhile, the slow speed of decreasing energy intensity

and carbon intensity in Hainan is reasonable. However, unlike these three provinces, other provinces cannot rely on energy imports from other areas, and coal is still their main energy resource. There are 14 provinces with significant high proportions of coal consumption which are more than 80%. There are 12 provinces with high proportions ranging from 50% to 80%. In these 26 provinces, decreasing speeds of coal proportion are relatively slow. Compared with 2005, Liaoning, Shaanxi, Qinghai, Henan and Yunnan have decreased their coal consumptions by more than 5%. On the contrary, some provinces are still increasing their coal proportions, including Heilongjiang, Guangdong, Guangxi, Xinjiang, Zhejiang, Gansu, Hubei, Jilin and Inner Mongolia, which are facing severe situations of energy consuming structure. In addition, situations in the other 12 provinces rarely changed. In general, the effort in energy consuming restructure is not enough. The trend study of coal proportion reveals problems that the analysis of energy intensity and carbon intensity cannot show. For example, although energy intensity and carbon intensity both decreased by large percentages in Inner Mongolia, the coal consumption and carbon emissions still remains high. Before the long term plans can make differences, the transformation of energy consuming structure should be promoted.

[Insert Table 8 here]

The national difficulty on energy conservation and emission reduction of the 12th FYP is caused by specific regional issues. First, regional process of energy saving is limited by economic growth. GDP growth is still the most important issue for government performance evaluation. The pressure on GDP growth may drive provincial government to develop industries that produce high economic return but also high emissions. Second, policies for rewards and punishments on energy saving and emission reduction assignments are not clear at provincial level. Thus, provincial government has lower motivation for energy saving and emission reduction. In addition, the specific data for provinces are not consistent with national data, which impedes the implementation of the policies.

5 Conclusion

China has recognized energy saving and emission reduction as an essential part in its economic development mode and industrial enhancement. The government kept making great effort on low-carbon conversion of high-carbon energy in the 12th FYP period following the 11th FYP period. However, the progress encounters difficulties in the first two years of the current FYP period. At the national level, the decreasing rate of energy intensity obviously decreased during 2011-2012. In spite of the accelerating decrease in 2013, the task for 2014-2015 is still challenging. On the other hand, although the control of carbon intensity brought an actual decrease of 4.1%, the present accomplishment is far below the national goal of 17% decrease. At the provincial level, situations in different regions vary significantly. In economic well-developed provinces, energy intensities continuously decrease at fast speeds and tend to exceed the goals. In some western provinces, the targets are difficult to complete in the remaining years of the 12th FYP period. Situations of carbon intensity are more severe. Only 1/3 of the provinces have met the requirements of their specific targets at current carbon intensity decreasing speeds.

In order to reach the goal by 2015, energy restructure should be more concerned. Although the coal proportion tends to meet the goal of 65% decrease by the end of the 12th FYP period, the carbon emission are not likely to decrease as expected. In current slow pace of energy restructure, alternative methods are to develop renewable energy and to switch high-carbon energy to low-carbon energy. Nowadays, China is the world's largest investor in renewable energy (Wang, 2013). Wind-power, solar-power and biogas are all

highly feasible. For low-carbon technique, in addition to the general method of increasing efficiency of coal consumption, substitutions of natural gas and IGCC technique are also consistent with national circumstances.

With more and more specific policies towards regional energy reduction and much more investment on environmental technique, China is on a reasonable path forward in energy conservation and emission reduction. Current situations require provincial governments to expedite their progress and be flexible to search for more appropriate approaches under specific circumstances.

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Tables and figures

Table 1 National energy intensity and national carbon intensity in 2005-2013

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013
Energy intensity (tce/ten thousand CNY)	1.276	1.241	1.179	1.117	1.077	1.033	1.012	0.973	0.937
Carbon intensity (tCO_2/ten thousand CNY)	2.773	2.916	2.825	2.781	2.689	2.784	2.820	2.670	N\A

Table 2 Completion and left target in the 11th FYP and the 12th FYP periods of national energy intensity and national carbon intensity

	Average annual decreasing rate in the 11th FYP period (2006-2010)	Accumulated decrease in the 11th FYP period (based on the level of 2005)	Average annual decreasing rate in the early years of the 12th FYP period	Accumulated decrease in the early years of 12th FYP period (based on the level of 2010)	Annual decreasing rate to reach the target for the left years of the 12th FYP period
Energy intensity	4.14%	19.10%	2.93% (2011-2013)	9.28% (2011-2013)	3.80% (2014-2015)
Carbon intensity	-0.08%	-0.40%	2.07% (2011-2012)	4.10% (2011-2012)	4.70% (2013-2015)

Table 3 Completion (2005-2012) and target (2013-2015) of decreasing regional energy intensity

Region	Energy intensity of 2005	Energy intensity of 2010	Accumulate decreasing rate of 11th FYP period (2010 compare with 2005)	Energy intensity of 2011	Energy intensity of 2012	Target decreasing rate of the 12th FYP period (2015 compare with 2010)	Annual targets for 2013-2015
Beijing	0.764	0.567	25.8%	0.533	0.512	17.0%	2.8%
Tianjin	1.009	0.806	20.1%	0.780	0.747	18.0%	4.0%*
Hebei	1.912	1.542	19.3%	1.499	1.417	17.0%	3.3%
Shanxi	2.908	2.274	21.8%	2.215	2.146	16.0%	3.8%*
Inner Mongolia	2.388	1.868	21.8%	1.838	1.756	15.0%	3.3%
Liaoning	1.632	1.319	19.2%	1.287	1.230	17.0%	3.8%*
Jilin	1.417	1.116	21.2%	1.086	1.017	16.0%	2.7%
Heilongjiang	1.409	1.127	20.0%	1.093	1.057	16.0%	3.6%*
Shanghai	0.858	0.695	19.1%	0.652	0.618	18.0%	2.7%
Jiangsu	0.891	0.717	19.5%	0.698	0.670	18.0%	4.3%*
Zhejiang	0.865	0.699	19.2%	0.685	0.649	18.0%	4.1%*
Anhui	1.173	0.944	19.5%	0.915	0.886	16.0%	3.6%*
Fujian	0.904	0.763	15.6%	0.745	0.710	16.0%	3.3%
Jiangxi	1.019	0.823	19.3%	0.805	0.765	16.0%	3.3%
Shandong	1.269	0.999	21.3%	0.971	0.936	17.0%	3.9%*
Henan	1.333	1.076	19.2%	1.045	0.983	16.0%	2.8%
Hubei	1.476	1.168	20.9%	1.135	1.099	16.0%	3.7%*
Hunan	1.420	1.142	19.6%	1.111	1.045	16.0%	2.8%
Guangdong	0.767	0.648	15.5%	0.629	0.601	18.0%	4.1%*
Guangxi	1.179	1.010	14.4%	0.985	0.953	15.0%	3.4%
Hainan	0.883	0.787	10.8%	0.837	0.817	10.0%	4.6%*
Chongqing	1.375	1.100	20.0%	1.069	1.003	16.0%	2.7%
Sichuan	1.544	1.242	19.5%	1.201	1.126	16.0%	2.5%
Guizhou	2.714	2.194	19.2%	2.137	2.070	15.0%	3.4%
Yunnan	1.679	1.401	16.6%	1.369	1.338	15.0%	3.8%*
Shaanxi	1.366	1.101	19.4%	1.073	1.045	16.0%	4.0%*
Gansu	2.179	1.756	19.4%	1.729	1.673	15.0%	3.7%*
Qinghai	2.966	2.487	16.2%	2.748	2.731	10.0%	6.4%*
Ningxia	3.994	3.225	19.3%	3.406	3.262	15.0%	5.6%*
Xinjiang	2.040	1.877	8.0%	2.027	2.179	10.0%	8.1%*

Note: * indicates annual target (2013-2015) higher than 3.5%

Table 4 Completion (2005-2012) and target (2013-2015) of decreasing regional carbon intensity

Region	Carbon intensity of 2005	Carbon intensity of 2010	Accumulate decreasing rate of 11th FYP period (2010 compared with 2005)	Carbon intensity of 2011	Carbon intensity of 2012	Target decreasing rate of the 12th FYP period (2015 compare with 2010)	Annual targets for 2013-2015
Beijing	1.384	1.039	24.90%	0.918	0.896	18%	1.64%
Tianjin	2.541	2.004	21.12%	1.924	1.819	19%	3.73%
Hebei	4.004	4.297	-7.32%	4.382	4.135	18%	5.19%*
Shanxi	7.720	7.518	2.61%	7.317	7.120	17%	4.30%
Inner Mongolia	6.872	7.200	-4.77%	8.219	7.393	16%	6.48%*
Liaoning	3.533	3.419	3.22%	3.270	3.062	18%	2.90%
Jilin	4.128	3.519	14.76%	3.634	3.290	17%	3.89%
Heilongjiang	3.137	2.847	9.25%	2.953	2.953	16%	6.79%*
Shanghai	1.779	1.518	14.68%	1.472	1.350	19%	3.08%
Jiangsu	1.874	1.950	-4.08%	2.008	1.925	19%	6.37%*
Zhejiang	1.699	1.773	-4.36%	1.762	1.650	19%	4.52%
Anhui	3.230	3.258	-0.89%	3.182	3.164	17%	5.10%*
Fujian	1.687	1.914	-13.47%	2.007	1.863	17.5%	5.36%*
Jiangxi	2.406	2.274	5.50%	2.298	2.085	17%	3.26%
Shandong	2.341	2.737	-16.95%	2.654	2.585	18%	4.60%
Henan	3.661	3.130	14.52%	3.106	2.655	17%	0.72%
Hubei	3.106	3.043	2.04%	3.158	3.053	17%	6.13%*
Hunan	2.559	2.418	5.53%	2.460	2.112	17%	1.69%
Guangdong	1.439	1.422	1.19%	1.451	1.334	19.5%	4.99%
Guangxi	2.311	2.543	-10.05%	2.584	2.498	16%	5.08%*
Hainan	1.845	2.312	-25.31%	2.736	2.769	11%	9.43%*
Chongqing	2.132	2.526	-18.52%	2.513	2.211	17%	1.76%
Sichuan	2.720	2.564	5.74%	2.279	2.199	17.5%	1.28%
Guizhou	8.693	7.026	19.17%	6.808	6.563	16%	3.48%
Yunnan	3.753	3.996	-6.47%	3.761	3.456	16.5%	1.16%
Shaanxi	3.471	3.627	-4.49%	3.537	3.392	17%	3.90%
Gansu	4.852	4.778	1.52%	4.879	4.839	16%	6.04%*
Qinghai	3.900	4.146	-6.29%	4.230	4.441	10%	5.64%*
Ningxia	7.146	11.413	-59.71%	15.217	13.873	16%	11.59%*
Xinjiang	4.003	4.733	-18.21%	5.235	5.900	11%	10.63%*

Note: * indicates annual target (2013-2015) higher than 5%

Table 5 Energy structure from 1990 to 2012

Year	Total energy consumption (10^4 tce)	As percentage of total energy consumption				Energy intensity	Carbon intensity
		Coal	Crude Oil	Natural Gas	Hydro-power, Nuclear Power, Wind Power		
1990	98703	76.2%	16.6%	2.1%	5.1%	-	-
2000	145531	69.2%	22.2%	2.2%	6.4%	-	-
2005	235997	70.8%	19.8%	2.6%	6.8%	-	-
2010	324939	68.0%	19.0%	4.4%	8.6%	1.033	2.779
2011	348002	68.4%	18.6%	5.0%	8.0%	1.012	2.803
2012	361732	66.6%	18.8%	5.2%	9.4%	0.973	2.671
2013(estimation)	375000	66.6%	18.8%	5.4%	9.2%	0.937	N/A

Table 6 Provincial targets of decreasing energy intensity (2013-2015)

Annual decreasing targets	Provinces
Over fulfill (Left annual target < 3%)	Beijing, Jilin, Shanghai, Henan, Hunan, Chongqing, Sichuan
Normal (Left annual target 3% < 4%)	Tianjin, Hebei, Inner Mongolia, Shanxi, Liaoning, Fujian, Jiangxi, Heilongjiang, Jiangsu, Zhejiang, Anhui, Shandong, Hubei, Guangdong, Guangxi, Guizhou, Yunnan, Shaanxi, Gansu, Hainan
Hard to complete (Left annual target > 4%)	Qinghai, Ningxia, Xinjiang

Table 7 Provincial targets of decreasing carbon intensity (2013-2015)

Annual decreasing targets	Provinces

Over fulfill (Left annual target < 3%)	Beijing, Tianjin, Liaoning, Shanghai, Henan, Hunan, Chongqing, Sichuan, Yunnan
Normal (Left annual target 3% < 5%)	Hebei, Shanxi, Jilin, Zhejiang, Jiangxi, Shandong, Guangdong, Guizhou, Shaanxi
Hard to complete (Left annual target > 5%)	Inner Mongolia, Heilongjiang, Jiangsu, Anhui, Fujian, Hubei, Guangxi, Hainan, Gansu, Qinghai, Ningxia, Xinjiang

Table 8 Provincial energy structures and their variation trends

Coal proportion	Feature	Provinces (decreasing rate of coal proportion during 2005-2012)
< 50%	Having low coal proportion and mainly relying on low-carbon energy	Beijing (35%), Shanghai (13%), Hainan (7%)
50%-80%	Apparent decrease on coal proportion	Liaoning (5%), Shaanxi (5%), Qinghai (6%)
	Essentially unchanged coal proportion	Tianjin (2%), Fujian (2%), Chongqing (1%), Sichuan (1%)
	Coal proportion tends to increase	Heilongjiang (-1%), Guangdong (-17%)*, Guangxi (-1%), Xinjiang (-16%)*, Zhejiang (-1%)
> 80%	Apparent decrease on coal proportion	Henan (5%), Yunnan (4%)
	Essentially unchanged coal proportion	Hebei (1%), Shanxi (3%), Jiangsu (2%), Jiangxi (1%), Shandong (1%), Hunan (3%), Guizhou (2%), Ningxia (0%)
	Coal proportion tends to increase	Gansu (-1%), Hubei (-1%), Jilin (-9%)*, Inner Mongolia (-1%)

Note: * indicates rapid growth on coal proportion that higher than 5%

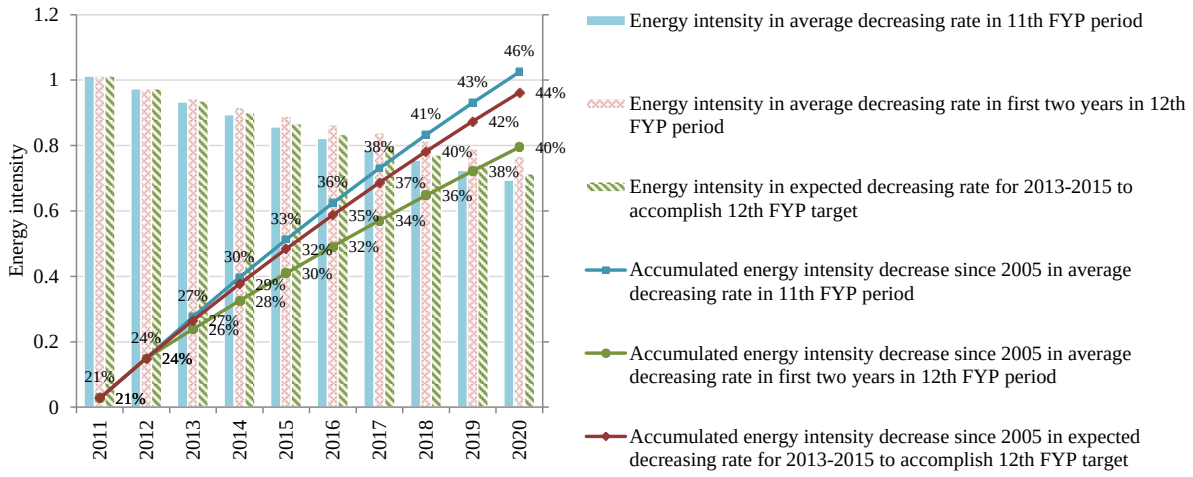

Figure 1 Predicted decrease of energy intensity in different decreasing rates in 11th and 12th FYP periods

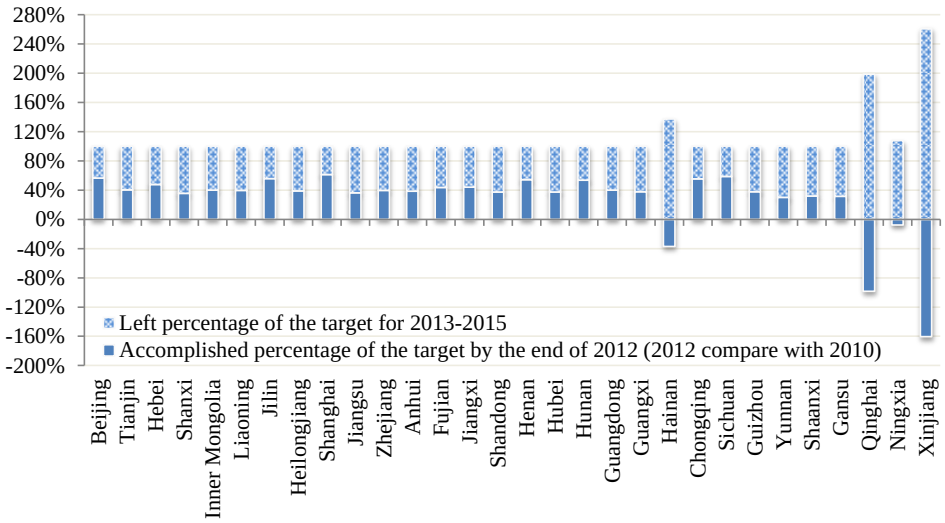

Figure 2 Ratio of accomplished and left targets of energy intensity of China's 30 provinces

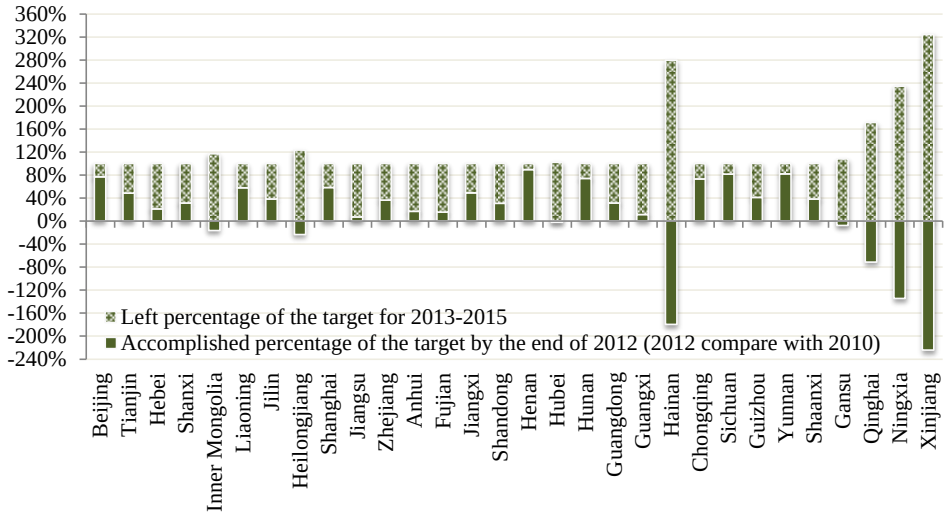

Figure 3 Ratio of accomplished and left targets of carbon intensity of China's 30 provinces