Deutsche Bank
Markets Research

Asia
China

Economics

Special Report

Date
9 June 2013

Jun Ma, Ph.D
Chief Economist
(+852) 2203 8308
jun.ma@db.com

Audrey Shi
Research Associate
(+852) 2203 6139
audrey.shi@db.com

Michael Tong, CFA
Research Analyst
(+852) 2203 6167
michael.tong@db.com

Big bang measures to fight air pollution (2nd edition)

This is the second edition of a report of the same title first published on March 1st. In this edition we updated some estimates and provided info on latest developments but the key policy conclusions remain unchanged.

Surge in PM2.5 and its health implications call for significant policy changes

With the surge in the air pollution index PM2.5 to nearly 1,000 in Beijing in mid-January (vs. WHO interim target of 25 and air quality guidance of 10), and the massive press coverage of its serious health implications, the public is now demanding immediate and material government actions to improve air quality. This report is the first study that quantifies the needed policy actions to achieve a reduction in PM2.5 to a safe level within a politically acceptable timetable.

Our PM2.5 reduction model shows that to reduce urban average PM2.5 to 30 by 2030, China should sharply reduce its coal and car consumption growth, and massively increase investments in clean energies and subways/railways.

We propose a policy package that can achieve a reduction of the urban average PM2.5 to 30 by 2030, which is implied by the government target for most cities to achieve 35. This package will require the following changes to current policies or plans, among others:

1. **Reduce the annual average coal consumption growth to 2.7% from the current forecast of a 4% CAGR for 2013-17, and cut coal consumption by 22% from 2017-30.** This means that China's coal consumption should peak in 2016, vs. the consensus projection of a peak around 2025.
2. **Reduce coal-related emissions by about 70% in the coming 18 years via clean coal technologies.**
3. **Reduce emissions per car by more than 80% by enforcing high standards for gasoline and car emission and improving fuel efficiency.**
4. **Increase the annual growth rate of clean energies (gas, nuclear, hydro, wind and solar) by another 4ppts for 2012-20 vs. the current forecast.**
5. **Reduce the 2030 target for passenger vehicles to 250mn units from the current expectation of 400mn.** This implies a reduction in annual average car sales growth to 6% during 2013-30 from 20% p.a. in the past five years.
6. **Increase the length of railways and subways by 60% and four-fold, respectively, from 2013-20, and further increase the length of railways and subways by 60% and 230%, respectively, from 2020-30.**

Our analysis shows that these new targets are technically achievable, and their impact on economic growth, fiscal balance, and inflation is manageable. It does, however, require a strong government will to overcome the opposition from interest groups.

Sectoral implications

While our proposal is indicative in nature, we are confident that actual policy changes can move in the same direction as suggested. This would mean a significant reduction in coal and car sales growth. In contrast, gas, nuclear, wind, solar and railway/subway construction would then likely see meaningful upward revisions to growth forecasts for many years to come.

Table Of Contents

Introduction: need to overhaul growth strategy[1]

Current policies are inconsistent with the target of reducing PM2.5

With the surge in the air quality index PM2.5 in Beijing and many other regions to near-catastrophic levels since January, as well as the growing public awareness of its serous health implications, the Chinese government has no choice but to double its efforts to control and reduce air pollution. The question is how. The Ministry of Environmental Protection has recently announced the target that by 2030 all cities should achieve level II air quality, which includes the requirement of reducing PM2.5 to 35. According to our research, this target implies a city average PM2.5 of 30 by 2030, given the dispersion of pollution levels among cities.

A fundamental problem with the current policies is that **they are inconsistent with the need to reduce pollution to politically acceptable levels within an acceptable period of time**. Let's look at three examples to illustrate this inconsistency.

1. **On coal consumption**, even if one assumes a slowdown to 4% per year in the coming decade from the 8% in the past five years, annual coal consumption will still rise to 5.6bn tons by 2022 from the current 3.8bn tons. According to Jiang Bin, Director of Planning Department of the State Energy Bureau, "if uncontrolled, China's coal consumption could rise to 10bn tons by 2030".[2] Even though the current plan stated that coal consumption should be controlled at 3.9bn tons by 2015, this limit will likely be breached in as early as 2013 according to forecasts of many analysts. We see nothing in the current policy that could meaningfully slow down the pace of coal consumption.

2. **On auto consumption,** influential voices from the auto sector suggest that the number of passenger cars in China should rise from the current 90mn to around 400mn in 2030. The government's emphasis on the development of smaller cities in its urbanization strategy – which rely less on mass public transport system such as subways – is also supportive of the rapid increase in the number of vehicles.

3. **On railways and subways**, the government's plan is to increase the total length of railways from 90,000km in 2011 to about 140,000km by 2020, and to increase the total length of subways to 7,000km by 2020 from the current 2,000km. Even with these seemingly ambitious targets, by 2020 the per capita length of railways in China will still be 1/8th of the OECD average, and the per capita length of subways in urban China will be only 1/5th of that in major cities in the world. According to our calculation, these targets essentially assume that public transportation can only grow at a maximum of 4% per year

[1] The authors of this report would like to thank the support of Boyuan Foundation for this research project. We should also thank Greenpeace, NDRC, State Council Development Research Center, Fudan University, Air Quality China, www.pm2d5.com and, in particular, Feng Fei, Wang Yuesi, Calvin Quek, Lauri Myllyvirta, Amy Zheng, Song Weimin, Vincent Ha, James Kan, Phyllis Wang, Eric Cheng, Zhou Wei, Guo Xuesong, Xiao Mingzhi and number of officials in China's environmental protection agencies for very useful discussions and for the contribution of data and views.

[2] http://finance.ifeng.com/roll/20101224/3109428.shtml.

(vs. 6.1% national traffic growth) in the coming 8 years, and therefore will fall sharply as a percentage of total traffic. In other words, the current plan for public transport systems implies that the number of private cars will have to rise at a pace of 8% p.a., or reach 400mn by 2030, a threefold increase from the current level.

4. **On pollution charges.** The current pollution charges in China are way too low relatively to the installation cost of pollution reduction facilities (such as desulfurization and denitration facilities). For example, the emission charge on SO_2 in China is less than 1/10 of those in Scandinavian countries. This system effectively encourages the generation of more emissions.

Therefore, the current sector trends (such as those for coal and auto) essentially mean that coal burning will rise by another 50%, and oil burning due to the rising number of cars on the road will increase by 300% in the coming 1-2 decades. If there is no improvement in emission standards and gasoline quality, China's air quality will worsen by another 80% (given coal burning accounts for about 45% of PM2.5 and car emissions for about 20%).

Of course, China can implement tougher emission standards on power and industrial use of coal, and raise the standards for fuel quality, car emissions and fuel efficiency. Our calculation shows that these measures will help, but they are not sufficient to reduce PM2.5 given the 50% rise in coal consumption and 300% rise in car ownership. With best efforts in emission controls via clean coal technologies, higher car emission standards and fuel efficiency, PM2.5 will likely remain around 45 in 2030.

To conclude so far, keeping all other things constant, **the current trend of coal and auto consumption growth implies that China's air pollution will become a lot worse from the already unbearable level. Without changing the coal and auto consumption trend, even if maximum efforts are made to enforce tougher emission standards, air quality will not improve to a safe level by 2030. In other words, a major change in the energy mix and a reduction in car consumption growth are a must if PM2.5 is to be reduced to a safe level.**

Need to quantify the required policy changes

The policy inconsistencies outlined above are a primary reason for the government's failure to control air pollution in the past, in our view. In our view, the reasons for the policy inconsistency are:

First, at the top level, this problem arose due to insufficient attention being paid to pollution, which in turn could be explained by insufficient public awareness about heath implications of poor air quality in the past.

Second, at the operational level, the planning agencies have come up with overall economic plans largely based on sectoral proposals (which largely reflect industries' self interests) but failed to impose top-down constraints related to environmental capacity (i.e. how much more pollutants the air and the water in China can accommodate without seriously harming people's health).

Third, **policy research so far has failed to quantify the need for total emission reductions and show how this emission reduction target should be decomposed – in a consistent manner -- to policy actions in coal, auto, new**

energies, clean tech, and public transport sectors. All policy recommendations (on reducing PM2.5) we have seen so far are either qualitative in nature (which is not very useful as no one knows to what extent these proposed policies can help), or focus only on a few elements that do not establish a link to the overall PM2.5 reduction target.

This report aims to fill this gap in policy research. In this report, we have constructed a PM2.5 reduction model, which allows us to simulate various policy actions and their impact on air pollution. We show quantitatively how China's growth strategy and key sector policies should change, in order to reduce urban average PM2.5 to 30 by 2030. Among the many conclusions, here are several highlights:

1. The reduction of urban average PM2.5 from the recent 65 to 30 by 2030 should first be decomposed into specific sources of emission reduction. Our proposed decomposition looks like the following:
    - 19% from reduction in coal consumption;
    - 42% from the use of clean coal technologies;
    - 19% from reduction in transport emissions;
    - 11% from reduction in construction/industrial-related emissions that are not related to coal and oil burning.
    - 8% from reduction in others.
2. To achieve the above decomposed targets especially on coal consumption, China should drastically change its energy mix. This means that China has to slow coal consumption growth in the next few years and begin to reduce coal consumption earlier (i.e., from 2017) than the current assumption of somewhere between 2020 and 2030. Simultaneously, policies promoting clean energies (such as gas, nuclear, hydro, wind and solar) have to become more aggressive.
3. To achieve the target for emission reduction from transportation, China should sharply reduce its expectation for auto penetration and substantially increase its planned investments in subway and railway in the coming two decades. The current policy preference for developing smaller cities contradicts the objective of improving energy efficiency and air quality, and should be replaced with a re-focus on developing large cities which can more efficiently adopt a mass urban transport system. The total length of railways and subways should increase about 60% and four-fold, respectively, from 2013-20, and further increase by about 60% and 230%, respectively, from 2020-30, in order to allow a meaningful reduction in car consumption growth from the current pace.

In addition to the above, we will discuss a range of specific policy changes that are required to achieve the clean air objective. These include stricter enforcement of SO_2/NO_X emission standards, major reforms on environmental levies and resource taxes, introduction of a car plate licensing auction system, relocation of newly approved coal plants to less densely populated west/central China, further emphasis on energy efficiency, application of stricter dust control policies to construction works, and tree planting.

Level, sources, and health implication of PM2.5

Recent urban average PM2.5 estimated at 65

China does not officially report urban average PM2.5, but as it is necessary for derive the required policy adjustments in our analysis. In this study, we use five methodologies/sources to estimate our own urban average PM2.5.

Source 1: Estimate based on 120 cities average PM10: 65

Data provided to us by Greenpeace International shows that past three years' annual average PM10 in 120 cities was 92.7, when calculated on a population weighted basis. The translation from PM10 to PM2.5 requires a conversion rate, which is estimated from 0.65 to 0.9 by various sources[3]. We take a conversion rate of 0.7, which yields an average PM2.5 of about 65.

Source 2: Estimate based on 2013 Q1 PM2.5 data in 71 cities: 75

Many cities started to report PM2.5 last year but a more complete data base only becomes available from the beginning of this year. We obtain a 71 cities' PM2.5 dataset for each day from January to March 2013 from Air Quality China and www.pm2d5.com. These data points gave an average of 95 for the 71 cities in Q1. Knowing that PM2.5 is typically higher in the winter than in other seasons, we used a seasonal factor (the ratio of Q1 PM2.5 to annual average PM2.5 at 125%) to estimate the urban average PM2.5. The result is about 75[4].

Source 3: MEP data on PM2.5 in seven cities: 53

The estimate is based on annual data reported by MEP for Tianjin, Shanghai, Chongqing, Suzhou, Guangzhou, Nanjing and Ningbo. It gives an annual average PM2.5 density of 53.2 μ g/m3 in 2010.[5]

Source 4: NASA data collected by satellite: 65

According to satellite-derived PM concentration, the 5-year average of PM2.5 Index in Eastern and Central China ranged from 50 to 80 during 2001-2006. We take 65 as the average.[6]

---

[3] "The Study of Air Pollution Concentrations of PM2.5, PM10 and NO2 at Ambient and Kerbsite and Their Correlation in Metro Cities"(R. Kumar et al, Environmental Monitor Assess) shows that the ratio between PM2.5 to PM10 ranges from 0.61–0.91.

[4] Our calculation of 2012 PM2.5 data of 20 cities including Beijing, Shanghai, Guangzhou, Nanjing, Hangzhou, Suzhou, Wuxi, Taizhou, Lianyungang, Ningbo and Jiaxing has shown that the Q1 average to annual average ratio varies from 105% to 137%, with an average of around 125%. This number is confirmed by several international studies as well.

[5] Ministry of Environmental Protection of PRC, China Air Pollution and Policy Strategy, May 2012

[6] NASA, New Map Offers a Global View of Health-Sapping Air Pollution, Sep 2012

Source 5: Michael Brauner et al: 63

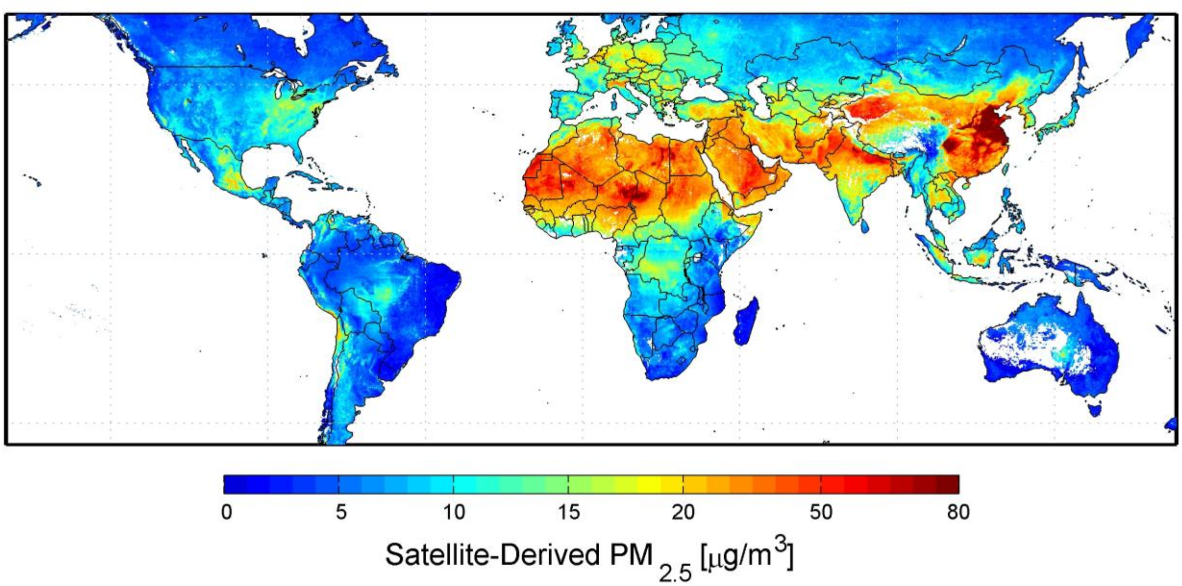
A study by Michael Brauner et al on Environmental Science & Technology, which uses satellite data, ground monitoring and model stimulation, shows that the population-weighted annual average PM2.5 in Eastern Asia was 55 in 2005.[7] We derive the China PM2.5 (63) based on population weights in East Asia.

The average of the aforementioned five estimates is about 65. In the following analysis, we will use this figure as the basis for calculating the required reduction in PM2.5 and the needed policy changes to achieve this goal. Note that although Beijing reported an average PM2.5 level of 153 in January, it partially reflects the seasonal pattern (winter is typically the worst in the year). Also, Beijing's PM2.5 is significantly worse than China's urban average.

International comparison of PM2.5

With the surge in PM2.5 in major Chinese cities, many people have also begun to pay attention to where China is in comparison with other countries (Figure 1), plotted by Donkelaar and Martin using the five-year average data from NASA from 2001 to 06, is the most popular among the general public in China. It shows that China has the highest density of dark red color (with PM2.5 approaching 80) compared with any other country in the world. It is now known that North America, most of Latin America, Australia and New Zealand, and Russia have their PM2.5 at or below 15.

Figure 1: Global satellite-derived map of average PM2.5 over five years



Source: NASA, New Map Offers a Global View of Health-Sapping Air Pollution, Sep 22 2010; Note: data range is 2001-2006 since no updated version is available

Comparison of city-level PM2.5

Since 2012, about 100 Chinese cities started to report PM2.5 data, among which about 70 cities have been reporting the data on an hourly basis in recent months. According to the database provided by Air Quality China and www.pm2d5.com, we calculated and

[7] Michael Brauer et al, Exposure Assessment for Estimation of the Global Burden of Disease Attributable to Outdoor Air Pollution, Environmental Science & Technology, 2012, 46, 652–660

ranked the PM2.5 quarterly average concentration for the 70 cities in 2013 Q1. As shown in Figure 2, the northern cities have recorded more higher pollution levels than southern cities. The reasons include 1) emission from coal-fired heating systems in winters in northern China; 2) concentration of major steel factories in the region of Beijing, Tianjin and Hebei, with intensive coal burning. Another material cause is the rapid growth of car ownerships in Beijing. By the end of 2012, Beijing had 4.08 million private cars, ranking number one among all cities nationwide. In contrast, Shanghai, with a similar population and a higher GDP, had only 1.41 million private cars, 1/3 of those in Beijing.

Figure 2: Average PM2.5 concentration in 2013 Q1 by Chinese city

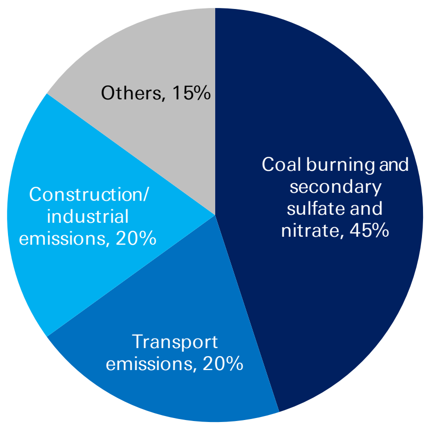
Rank	City	PM2.5 Concentration (μg/m3)	Rank	City	PM2.5 Concentration (μg/m3)	Rank	City	PM2.5 Concentration (μg/m3)
1	**Shijiazhuang**	217.1	26	Xuzhou	98.8	51	Taizhou	69.8
2	Baoding	190.0	27	**Nanjing**	98.4	52	**Guiyang**	69.3
3	Handan	185.6	28	Changzhou	98.2	53	**Yinchuan**	66.5
4	**Xi'an**	177.9	29	Wuxi	97.1	54	**Nanning**	65.9
5	Langfang	175.7	30	**Xining**	96.2	55	**Guangzhou**	64.2
6	Hengshui	170.5	31	**Nanchang**	94.9	56	Lishui	63.9
7	Tangshan	163.1	32	Zhenjiang	93.6	57	Ningbo	62.6
8	**Jinan**	159.0	33	Yangzhou	93.4	58	Foshan	59.3
9	**Urumqi**	158.9	34	Qingdao	92.9	59	Zhaoqing	58.2
10	**Zhengzhou**	152.8	35	**Chongqing**	92.0	60	Zhongshan	56.9
11	**Chengdu**	138.4	36	Yancheng	90.3	61	Jiangmen	56.1
12	**Wuhan**	133.4	37	**Lanzhou**	88.7	62	Dongguan	55.8
13	**Tianjin**	123.9	38	Suzhou	86.4	63	Zhangjiakou	53.9
14	**Beijing**	118.9	39	Nantong	86.3	64	**Kunming**	50.1
15	**Shenyang**	117.0	40	Shaoxing	85.2	65	Zhuhai	49.4
16	**Changsha**	115.7	41	Jinhua	84.0	66	**Shenzhen**	47.3
17	**Harbin**	114.0	42	**Hangzhou**	83.0	67	Shuizhou	44.0
18	**Taiyuan**	113.3	43	Suqian	82.4	68	**Fuzhou**	43.0
19	**Changchun**	107.2	44	**Hohhot**	81.9	69	Xiamen	39.0
20	Taizhou	101.7	45	Wenzhou	79.8	70	**Lhasa**	36.8
21	**Hefei**	100.5	46	Quzhou	77.6	71	**Haikou**	31.3
22	Qinghuangdao	100.4	47	Dalian	76.4			
23	Huaian	99.9	48	**Shanghai**	74.3			
24	Huzhou	99.5	49	Lianyungang	73.8			
25	Jiaxing	99.0	50	Chengde	72.7			

Source: Deutsche Bank, Air Quality China, www.pm2d5.com; Note: All provincial capitals are included and marked in bold.

Sources of PM2.5 in China

To effectively reduce PM2.5 in China, one needs to know where it is coming from. We estimate, based on a number of research studies, that the composition of PM2.5 in Chinese cities is roughly the following: 45% from coal burning and its secondary sulfate and nitrate, 20% from transport-related emissions, 20% from construction (e.g., dust) and industrial activities (emissions not related to coal burning; such as emissions from other commercial fuels and industrial emission of VOC), and 15% from other sources including biomass combustion, fertilizers, pesticides, plantation, cooking, smoking, forestry and ocean (Figure 3). This composition will be used in our PM2.5 reduction model as an important assumption (see next chapter).

Figure 3: Current composition of PM2.5 in China



Source: Deutsche Bank

The several references we use are as follows. Data provided by Greenpeace International to us shows that coal-related emission contributes 49% of PM2.5, and oil burning in transport sector contributes about 16% (Figure 4). This view is largely confirmed by Prof. HU Min, director of environmental and pollution control lab at Peking University, who says that 60-70% of PM2.5 emissions are due to coal and oil burning.[8]

Figure 4: Estimated sector shares of PM2.5 exposure by Greenpeace International

Power plants - coal	17%
Industry – coal	19%
Industry – other	17%
Transport – oil	**16%**
Urban residential & commercial - coal	4%
Urban residential & commercial - other commercial fuels	16%
Rural - coal	8%
Rural - biomass	1%
Rural - other commercial fuels	2%
Total	100%
Coal related share	**49%**

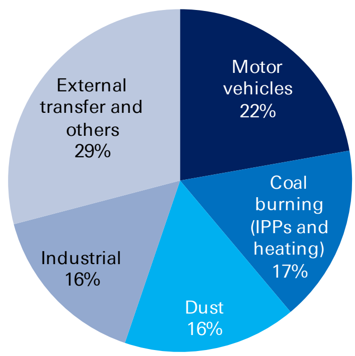
Source: Greenpeace International

According to Dr. Wang Yuesi of the Chinese Academy of Sciences, the main sources of PM2.5 in Beijing are vehicle exhausts (22%) and coal burning (17%); other sources include dust, industrial emission and external transfer (Figure 5). Nonetheless, just as Dr. Wang pointed out, as part of industrial emission and external transfer should be attributed to coal and fuel, these two reasons could possibly explain 80% of this round of PM2.5 in Beijing.

As for industrial breakdown, China's first national pollution census in 2007 suggests that gaseous pollutants are mainly emitted by three industries: thermal power, cement and steel (Figures 6-8).

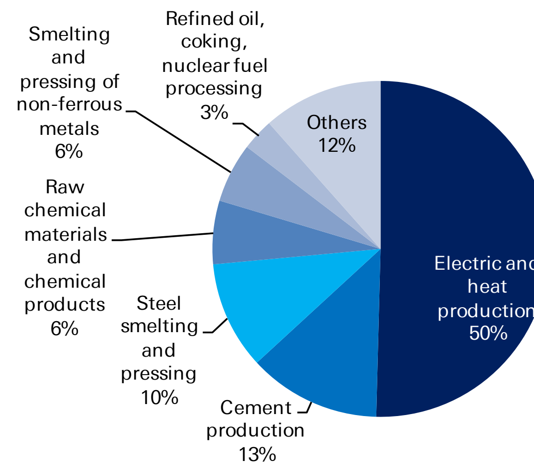
8 http://news.10jqka.com.cn/20130121/c532376080.shtml.

Figure 5: Source contribution of PM2.5 in Beijing



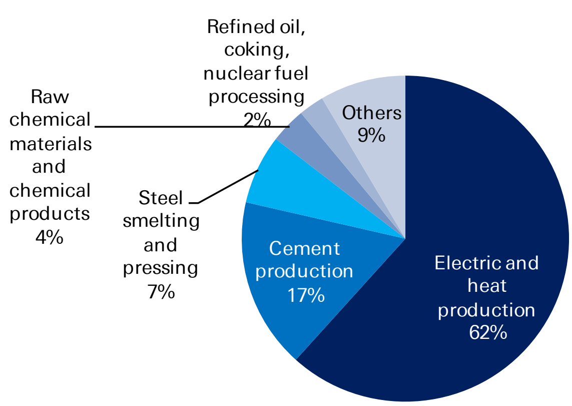
Source: Chinese Academy of Sciences

Figure 6: Industrial sources of sulphur dioxide emission



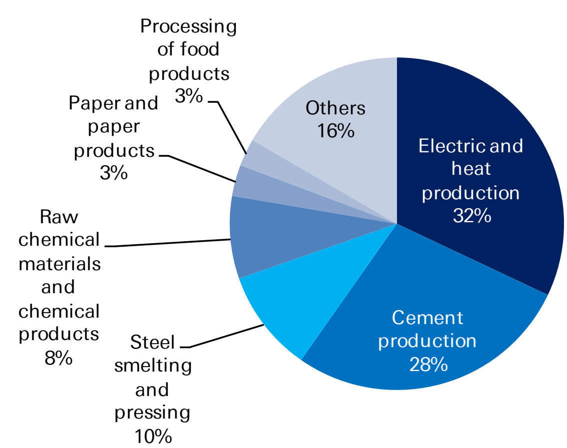
Source: China 1st national pollution census, NBS,

Figure 7: Industrial sources of nitrogen oxides emission



Source: China 1st national pollution census, NBS

Figure 8: Industrial sources of smoke emission



Source: China 1st national pollution census, NBS

Health implications of PM2.5

On 13 January, Beijing's PM2.5 – an air pollution index that measures the density of particulate matter (less than 2.5 micrometres in diameter) per cubic meter – once exceeded 900 amid heavy smog. Following that, the municipal government issued warnings to its citizens advising them to stay indoors as much as possible in order to avoid respiratory problems due to the extremely high levels of pollution. Note that the interim target of PM2.5 recommended by the World Health Organization is only 25. On 29 January, Beijing reported that it experienced heavy smog for a fourth time in a month.

Not only Beijing, but also most of China's east and middle regions suffered from elevated PM2.5. According to the Ministry of Environmental Protection (MEP), more than 600mn people in 17 provinces have been affected since mid-January. In Shijiazhuang, Hebei Province, the index even exceeded 1,000. The hazardous smog has caused widespread concerns about its health implications and rapidly rising public discontent.

According to China's new national standard for evaluating air quality, only 20.5% of the cities meet the standard.[9]

Several studies by Chinese and foreign scholars have revealed some alarming statistics on PM2.5's health implications for the public:

On acute health impact:

1. According to the empirical study by Xie et al (2009), in Shanghai, Hong Kong, Beijing, Wuhan and Taiyuan[10], **an increase in the PM2.5 index by 10 μg/m3 raises the death rate, cardiovascular mortality and respiratory disease mortality by 0.4%, 0.53% and 1.43% respectively** (Figure 10).

2. A joint study by Greenpeace and the School of Health, Peking University, estimates that high PM2.5 **pollution caused 7,770 premature deaths and RMB6.17bn in economic losses in Beijing, Shanghai, Guangzhou and Xi'an in 2010[11].**

On comprehensive health impact with chronic diseases:

1. A recent study by United States Institute for Health Metrics and Evaluation and Tsinghua University found that outdoor air pollution has caused, in 2010 alone, premature deaths of 1.234 million and a total loss of 25 million life years in China.[12]

2. According to Dr. Brian Miller's report published by London municipal government, **a permanent increase in the PM2.5 index by 1 μg/m3 reduces the average life expectancy of residents by three weeks[13].**

3. According to a study by Pope et al (2009) based on data from 51 cities in the US, **life expectancy falls by about two years when PM2.5 rises from 10 to 30 (Figure 9)[14].**

---

[9] This new standard is set at 70 μg/m3 for PM10. See Zhou Hongchun, "Pay High Attention to PM2.5 Pollution and Treatment," State Council Development Research Center Report, December 2012

[10] Source: Xie et al. Exposure-response functions for health effects of ambient particulate matter pollution applicable for China, China Environmental Science, Issue 10, 2009

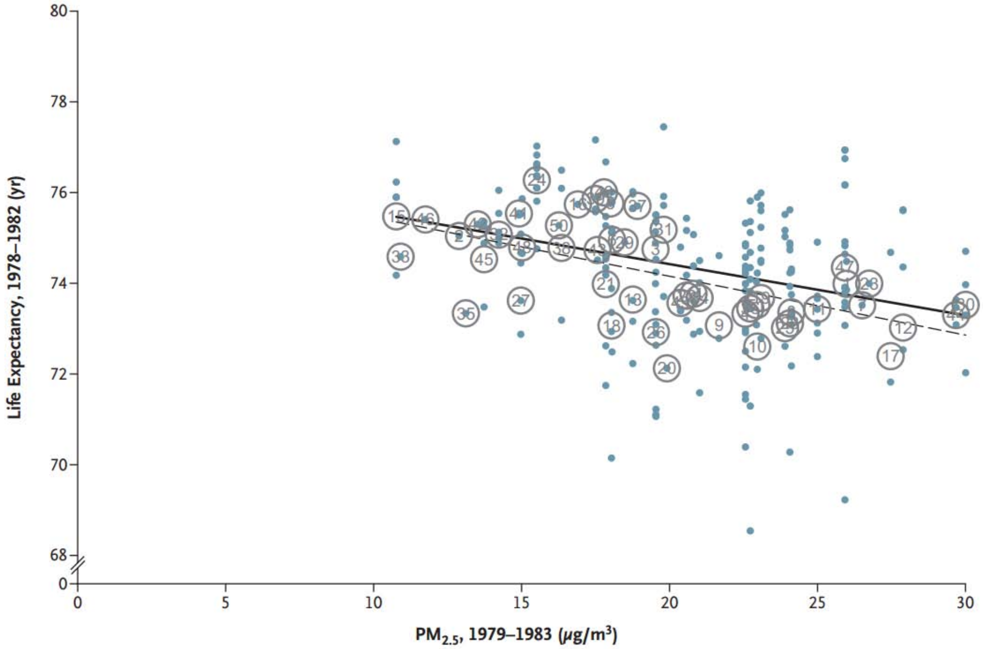
[11] Greenpeace, Peking University, Dangerous Breathing -- PM2.5: Measuring the human health and economic impacts on China's largest cities, http://www.greenpeace.org/, December 2012

[12] Institute for Health Metrics and Evaluation, Global Burden of Disease Study 2010, The Lancet : Volume 380, Number 9859, December 2012

[13] Dr. Brian G Miller, Report on estimation of mortality impacts of particulate air pollution in London, Consulting report P951-001, June 2010.

[14] Pope et al, Fine-Particulate Air Pollution and Life Expectancy in the United States, NEJM, January, 2009

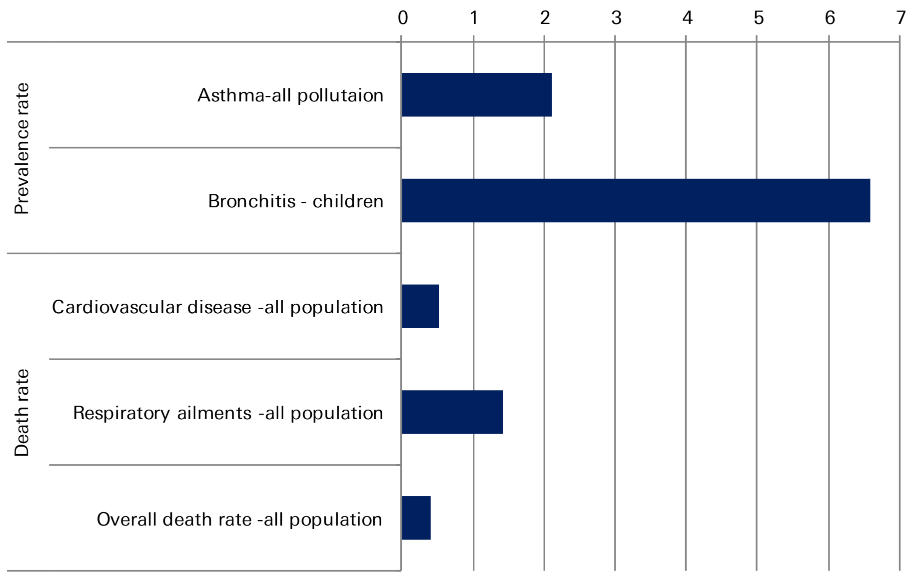
Figure 9: Life expectancies plotted against PM2.5, 1978-1982, US



Source: Pope et al, Fine-Particulate Air Pollution and Life Expectancy in the United States, NEJM, 2009; Dots and circles labeled with numbers represent population-weighted mean life expectancies at the county level and the metropolitan-area level, respectively. The solid and broken lines represent regression lines with the use of county-level and metropolitan-area–level observations, respectively. The metropolitan areas are coded by number as follows: 1 — Akron, Ohio; 2 — Albuquerque, New Mexico; 3 — Allentown, Pennsylvania; 4 — Atlanta; 5 — Boise, Idaho; 6 — Boston; 7 — Buffalo, New York; 8 — Charlotte, North Carolina; 9 — Charleston, West Virginia; 10 — Chicago; 11 — Cincinnati; 12 — Cleveland; 13 — Dallas; 14 — Dayton, Ohio; 15 — Denver; 16 — El Paso, Texas; 17 — Gary, Indiana; 18 — Houston; 19 — Indianapolis; 20 — Jersey City, New Jersey; 21 — Kansas City, Missouri; 22 — Little Rock, Arkansas; 23 — Los Angeles; 24 — Minneapolis; 25 — New York City; 26 — Norfolk, Virginia; 27 — Oklahoma City; 28 — Philadelphia; 29 — Phoenix, Arizona; 30 — Pittsburgh; 31 — Portland, Oregon; 32 — Providence, Rhode Island; 33 — Pueblo, Colorado; 34 — Raleigh, North Carolina; 35 — Reno, Nevada; 36 — St. Louis; 37 — San Diego, California; 38 — San Francisco; 39 — Salt Lake City; 40 — San Jose, California; 41 — Seattle; 42 — Spokane, Washington; 43 — Springfield, Massachusetts; 44 — Steubenville, Ohio; 45 — Tampa, Florida; 46 — Topeka, Kansas; 47 — Washington, D.C.; 48 — Wichita, Kansas; 49 — Wilmington, Delaware; 50 — Worcester, Massachusetts; 51 — Youngstown, Ohio.

The sudden increase in the awareness of the health impact of high PM2.5 has led to a heightened public pressure on the government to take aggressive actions. On Internet, some commentators ask that "if the consequence of strong economic growth is a decline in the people's life expectancy, what is the purpose of all that?" According to Baidu, the largest Chinese search engine, the search for "PM2.5" soared 35 times within a week from 7-13 January. It was also one of the most heated topics on Sina Weibo in January, discussed by 3,146,495 pieces of netizens' remarks (comments not included). Many members of the National People's Congress (NPC) and the Chinese People's Political Consultative Conference (CPPCC) also highlighted the urgency of anti-pollution polices to the government during the March NPC and CPPCC sessions. Under these pressures, we believe the government will have no choice but to take more drastic actions to fight air pollution.

Figure 10: The ppt increase in death/prevalence rate as a result of an increase in PM2.5 by 10 μg/m3



Source: Xie et al. Exposure-response functions for health effects of ambient particulate matter pollution applicable for China, China Environmental Science, Issue 10, 2009

Policies to reduce PM2.5 to 30 by 2030

This section examines the most important reforms (policy changes) that China needs to undertake in order to reduce PM2.5 to a safe level within a politically acceptable time table. Our key conclusions are: China will have to significantly reduce its growth rate of coal consumption, sharply increase the use of clean energies, speed up its pace of desulphurization and denitration, quickly implement the National V standards for gasoline and car emissions, improve fuel efficiency, slow the pace of car ownership growth, further increase its planned investment in subways and railways, and accelerate the pace of resource pricing reform as well as the resource and environmental tax reform, among others.

We kick off the analysis in Section I by estimating the needed reduction in urban average PM2.5 in order to achieve the government target for 2030. In Section II we conclude that the annual reduction in PM2.5 will have to be twice as fast as stated in the 12^{th} five year plan, if the 2030 target for PM2.5 is to be achieved.

We then, in Section III, construct a PM2.5 forecast model, based on which we propose a policy package that can achieve the goal of reducing urban average PM2.5 to 30 by 2030. Our proposed policy package involve, among others, a 0.8% annual average reduction in coal consumption, a 6% annual average reduction in emission via desulphurization/denitration and other clean coal technologies, and a 4% annual average reduction in transport emission between 2013 and 2030. In the last few sections, we will discuss more specific reform measures that could help achieve these policy goals.

Setting a target of reducing urban average PM2.5 to 30 by 2030

On January 24, Zhou Shengxian, Minister of Environmental Protection proclaimed that the government will try its best to achieve “Grade II Standard” of air quality in all cities (meaning each and every city) by 2030. Note that a major requirement of Grade II Standard is that PM2.5 annual concentration is at or below 35.

Note that “each and every city meeting the PM2.5 target” is different from “urban averaging meeting the PM2.5 target”. We believe this the stated objective by the government – each and every city reducing its PM2.5 to 35 -- implies an urban average target of no more than 30 due to the dispersion of PM2.5 distribution among cities.. We estimate that, even if the dispersion coefficient (currently at 0.42) among cities is reduced by half in the coming 18 years, for 90% of the cities to reach the PM2.5 target of 35 by 2030, the urban average PM2.5 will have to decline to 30. Accordingly, we translate the aforementioned government PM2.5 target for 2030 into an urban average target of 30. In the remainder of this report, our estimates of required policy actions are largely based on the current urban average PM2.5 at 65 and the urban average target of 30 for 2030.

Pace of PM2.5 reduction should double that set by 12th five year plan

To reduce urban average PM2.5 from the current 65 to 30, this index will have to come down by 54%. This implies that **China needs to reduce PM2.5 by 4% per year in the next 18 years.** For cities like Beijing, where PM2.5 is more than twice the national average, it will have to double or triple its efforts. We think setting this ambitious goal is politically necessary, as one commentator put it on the web, “we cannot afford to let our entire next generation live in polluted air”.

The 4% annual average reduction in PM2.5 is twice as fast as required by the 12th Five Year Plan. On December 5 2012, the Ministry of Environmental Protection (MEP) revealed the “Plan of Combating Air Pollution in Major Areas”《重点区域大气污染防治“十二五”规划》. This plan requires a reduction of the annual average PM2.5 by only 6% in three major areas, including Beijing-Tianjin-Hebei, the Pearl River Delta area, and the Yangtze River Delta area in the next three years. For Beijing, the target is to reduce PM2.5 by 15% by 2015.

However, we believe that this set of MEP targets is unlikely to be accepted by the public, which is increasingly aware of serious health implications of PM2.5. If the annual average reduction rate is 6% for the next three years, it translates into only a 2% reduction in PM2.5 per year. **Assuming this pace (2% reduction per year) applies to China as a whole, it would take 38 years to achieve the standard of 30.** This means that nearly two more generations will have to live in dirty air. Very few people have the patience or the lifespan to wait until 2050 to begin to breathe without fear for getting a lung cancer.

The biggest worry among many officials is that if policies to control air pollution are too aggressive, economic growth will slow drastically. However, very few people have done a serious calculation on whether the Chinese economy can absorb the impact of 4% annual average reduction in PM2.5. We have made an attempt in this report. **Our conclusion is that, if policies are properly designed, it is perfectly possible for China to avoid a sharp slowdown in economic growth while achieving its goal of reducing PM2.5 to 30 by 2030.** The following subsections present the details of our quantitative analysis on the feasibility of this program.

Our PM2.5 reduction model: deriving policy targets

PM2.5 reduction model

In this section, we present our quantitative PM2.5 reduction model. This model is used to derive the specific policy targets given the objective of reducing PM2.5 to 30 by 2030. The application of such a model would make sure that the final outcome of the sectoral targets (e.g. for coal, auto, and public transportation) would be consistent with the environmental target, thus resolving the policy inconsistency that we pointed out in the introductory chapter.

The overall structure of the model is illustrated in Figure 11. The model simulation takes the following major steps:

Step One: Setting targets for PM2.5, economic growth, and energy/traffic elasticity

1. **The PM2.5 reduction target**: China urban average PM2.5 will have to decline to 30 by 2030.

2. **GDP growth**: we assume real GDP growth to slow gradually from the current 8.2% (in 2013) towards 5.5% in 2030, reflecting the change in growth potential. The annual average GDP growth will be 6.8% from 2013-30.

3. **Energy elasticity**: we assume an energy elasticity of 0.5, implying that for each 1% increase in GDP, energy consumption growth will be 0.5%. This is broadly consistent with European countries' experience.

4. **Traffic elasticity**: we assume a traffic elasticity of 0.8, implying that for each 1% increase in GDP, traffic growth will be 0.8%. This is broadly consistent with China's historical and international experiences.

Step Two: Deriving energy consumption and traffic consumption growth

Given the above assumptions, we can derive energy consumption growth (annual average of 3.4% from 2013-30) and overall traffic growth (annual average of 5.5% from 2013-2030).

Step Three: Estimating emission reduction potential via higher emission standards and clean technologies

We estimate a large number of coefficients related to potential emission reduction via emission control actions such as desulphurization, denitration, higher fuel quality, fuel efficiency, and car emission standards. For example, we estimate that emission per ton of coal consumption can be reduced by 69% via clean coal technologies, and emission per car can be reduced by 82% via higher fuel quality, fuel efficiency, and car emission standards.

Step Four: Estimating the need for change in the energy mix and the mix of transport modes

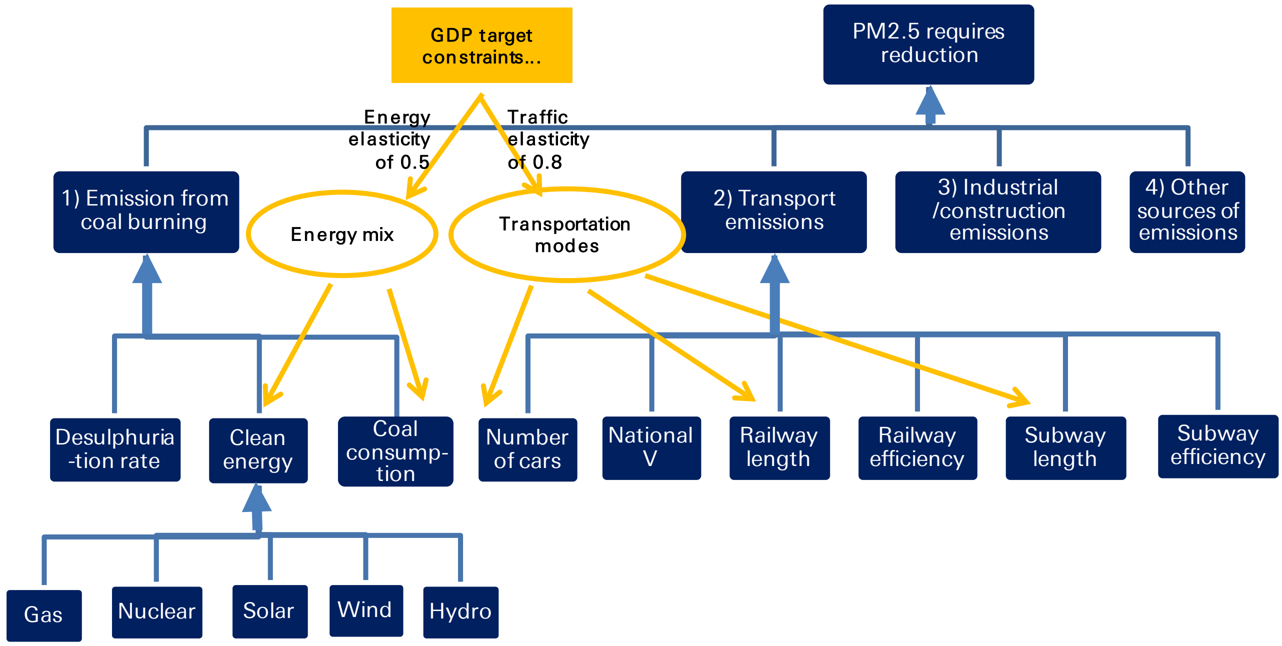
Given the above parameters, we estimate the required change in the energy mix (namely less coal, more clean energies), and the required change in the mix of transport modes (namely, more railway/subway transport, less road transport) in order to reach the PM2.5 target. Of course, there are multiple solutions to this exercise (many different combinations of energy and transport mixes can get us to the same final PM2.5 target), but we narrow down the options by taking into account factors such as the availability of natural resources (such as gas and wind), technical feasibility, and international experience (e.g. on railway and subway density, and on energy mix).

Step Five: Estimating the growth rates of all energies, number of vehicles on the road and railway/subway length

With the estimated changes in energy mix, we will be able to calculate the growth rates of coal consumption as well as the consumption of clean energies. With the estimated change in the mix of transport mode and the resulting railway, subway, and road traffic growth rates, we can also estimate the number of vehicles on the road, as well as the total lengths of railways and subways. Note that in our calculations, we also take into account many other factors such as the declining car usage rate, the increase in railway efficiency, as well as the need to allow other transport modes (such as air travel) to grow.

We will elaborate on the key results (sector growth targets) of this simulation in the following sector.

Figure 11: Our PM2.5 reduction model



Source: Deutsche Bank

Decomposing the PM2.5 target to policy targets

Based on the composition of PM2.5 that we estimated in the previous chapter (see Figure 13 reproduced below), coal burning and transport emissions represent about 65% of the total PM2.5. That means most of the policy efforts should be made to go towards reducing these sources of PM2.5. In addition, we assume that construction/industrial/other sources of PM2.5 can be reduced by 29% in the coming 18 years (for reasons to be explained later). Given these parameters and the PM2.5 reduction target, our simulation proposes the following policy targets from 2013-30:

1. **A 0.8% annual average reduction in coal consumption;**

2. **A 6% annual average reduction in coal-related emissions due to improvement in desulphurization/denitration and application of other clean coal technologies;**

3. **A 4% annual average reduction in vehicle exhaust emission, achieved by decelerating car ownership growth, a 1% annual average increase in fuel efficiency, and a 8% annual average reduction in emissions via enforcing higher fuel and emission standards as well as usage of more electric cars and cars powered by natural gas;**

4. **Limit the number of passenger vehicles on the road to 250mn by 2030, as opposed to the market expectation of around 400mn;**

5. **Increase the lengths of railways and subways by 60% and four-fold respectively from 2013-20, and further increase the lengths of railways and subways by 60% and 230%, respectively, from 2020-30;**

6. **Increase clean energy consumption as % of total energy consumption from the current 13% to 27% in 2020 and 46% in 2030.**

7. **A range of other measures including major reforms of environmental and resource levies/taxes, introduction of a car plate licensing auction system, acceleration in the adoption of the central heating system, relocation of newly approved coal plants to less densely populated west/central area, and further emphasis on energy efficiency.**

This policy package can reduce PM2.5 levels largely by cutting the emissions from coal and oil burning. With this package, we estimate that the reduction of PM2.5 level from 65 to 30 in the coming 18 years can be decomposed into the following (Figures 12-13):

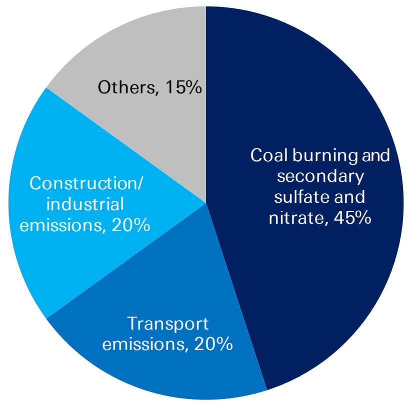
- 19% from reduction in coal consumption;
- 42% from the use of clean coal technologies;
- 19% from reduction in transport emissions;
- 11% from reduction in construction/industrial-related emissions. We believe that this is achievable as real estate construction will likely peak in a few years due to the sharp rise in per capita living space in the past decade, industrial activities will likely be cleaner as China's economic structure is shifting away from heavy manufacturing towards services, better dust control measures and emission standards in construction and industrial activities can be implemented, and more stringent VOC content limits can be imposed on industrial products.
- 8% from reduction in others. This requires a wider range of actions, such as tree planting, promotion of organic farming (reduction in the use of pesticides and fertilizers), adoption of technologies to improve efficiency of biomass combustion, reduction in the use of plastic bags and oil paints, as well as promotion of oil-less frying in cooking.

Figure 12: Decomposition of PM2.5 reduction to sources

	Weight	Reduction (%)	Contribution to reduction in PM2.5
Emission from coal burning	45%	-74%	62%
Reduction in coal consumption		-14%	19%
Reduction via clean coal tech		-69%	42%
Reduction in transport emissions	20%	-50%	19%
Reduction in construction/industrial emissions	20%	-30%	11%
Reduction in others	15%	-30%	8%

Source: Deutsche Bank

Figure 13: Current composition of PM2.5 in China



Source: Deutsche Bank

Figure 14 shows the forecast for all key variables in our PM2.5 reduction model from 2013-30.

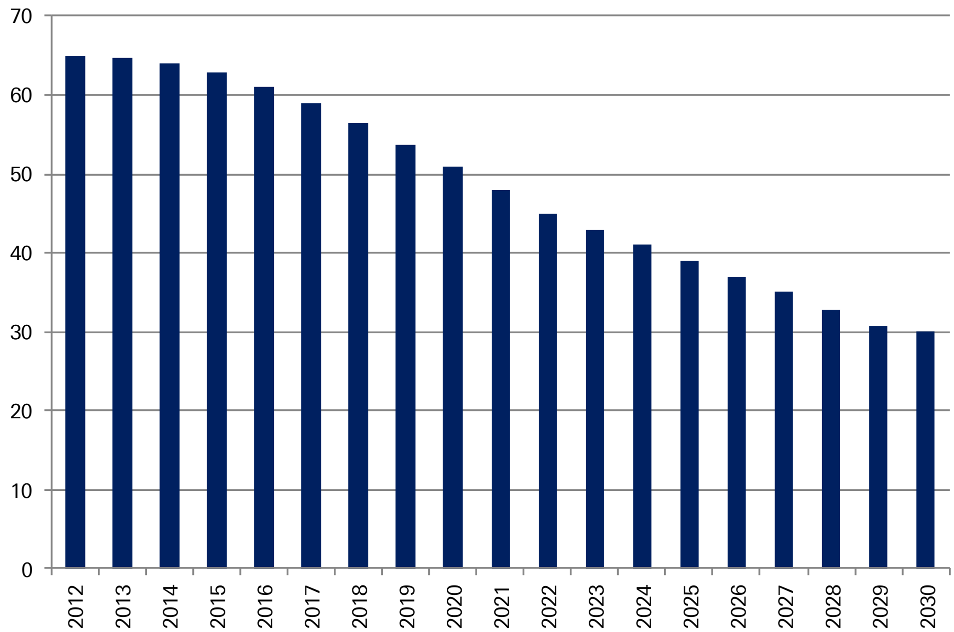
Figure 14: Sector targets derived from our PM2.5 reduction model, 2012-30

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
PM2.5	65.0	64.7	64.0	62.9	61.3	59.1	56.7	54.0	51.2	48.2	45.2	43.3	41.3	39.3	37.3	35.2	33.1	30.9	30.0
Coal emissions	29.3	29.2	28.8	28.2	27.1	25.6	24.1	22.4	20.6	19.0	17.3	15.8	14.3	12.8	11.4	10.1	8.8	7.5	7.7
Transport emissions	13.0	12.7	12.3	11.8	11.3	10.7	10.0	9.2	8.3	7.3	6.2	6.3	6.3	6.4	6.4	6.4	6.4	6.4	6.4
Road transport	9.1	8.8	8.4	8.0	7.4	6.8	6.1	5.4	4.5	3.5	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3
Railway/subway	1.0	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.1	1.1	1.0
Other transport	2.9	2.8	2.8	2.7	2.7	2.6	2.6	2.5	2.5	2.4	2.4	2.3	2.3	2.3	2.2	2.2	2.1	2.1	2.1
Construction/Industrial	13.0	13.3	13.5	13.7	13.9	14.0	14.0	14.0	14.0	13.8	13.7	13.4	13.1	12.6	12.1	11.5	10.8	10.1	9.2
Others	9.8	9.6	9.4	9.2	9.0	8.8	8.6	8.5	8.3	8.1	8.0	7.8	7.7	7.5	7.3	7.2	7.1	6.9	6.8
Coal Desulphurization/Denitration	36%	35%	33%	32%	30%	29%	27%	26%	24%	23%	21%	20%	18%	17%	15%	14%	12%	11%	11%
Fuel/auto standards + fuel efficiency	100%	92%	84%	75%	67%	59%	51%	42%	34%	26%	18%	18%	18%	18%	18%	18%	18%	18%	18%
Const/Indu emission control	100%	96%	92%	88%	84%	80%	76%	72%	68%	64%	60%	56%	52%	48%	44%	40%	36%	32%	28%
Coal/energy ratio	67%	67%	67%	66%	64%	61%	59%	56%	53%	50%	47%	45%	43%	41%	39%	37%	35%	33%	32%
Coal consumption (100 mn ton)	37	39	40	41	41	41	41	40	39	38	38	37	36	35	35	34	33	33	32
Road traffic/total transport ratio	55%	54%	54%	53%	52%	52%	51%	50%	50%	49%	48%	48%	47%	46%	46%	45%	45%	44%	44%
Road traffic growth		5.2%	5.1%	4.9%	4.8%	4.7%	4.5%	4.4%	4.3%	4.2%	4.1%	3.9%	3.8%	3.7%	3.5%	3.4%	3.3%	3.2%	3.0%
KM driven per road vehicle (index)	100%	99%	98%	96%	95%	94%	93%	92%	90%	89%	88%	87%	86%	84%	83%	82%	81%	80%	78%
Nominal road vehicle number	110	117	125	132	141	149	158	167	176	186	196	207	218	229	240	252	264	277	290
Nominal PV number	90	96	103	110	117	125	132	141	149	158	167	177	187	198	208	220	231	243	255
Growth of PV ownership		6.9%	6.8%	6.7%	6.6%	6.4%	6.3%	6.2%	6.1%	6.0%	5.9%	5.8%	5.7%	5.6%	5.5%	5.3%	5.2%	5.1%	5.0%
PV penetration	6.7%	7.1%	7.5%	8.0%	8.5%	9.0%	9.5%	10.1%	10.6%	11.3%	11.9%	12.6%	13.3%	14.0%	14.7%	15.5%	16.3%	17.2%	18.1%
Population (mn)	1354	1,363	1,371	1,378	1,384	1,390	1,395	1,399	1,403	1,406	1,408	1,410	1,412	1,413	1,414	1,414	1,414	1,414	1,413
Rail/subway traffic growth	8.1%	8.5%	8.4%	8.2%	8.0%	7.9%	7.7%	7.5%	7.4%	7.1%	7.0%	6.8%	6.6%	6.5%	6.3%	6.2%	6.0%	5.8%	5.7%
Vol index	100	109	118	127	137	148	160	172	184	198	211	226	241	256	272	289	307	324	343
Emission redu rate	100%	96%	92%	88%	84%	80%	76%	72%	68%	64%	60%	56%	52%	48%	44%	40%	36%	32%	28%
Total energy consumption growth (%	3.9	4.1	4.0	3.9	3.9	3.8	3.7	3.6	3.5	3.5	3.4	3.3	3.2	3.1	3.1	3.0	2.9	2.8	2.7
Total traffic growth (%)	6.2	6.6	6.4	6.3	6.2	6.0	5.9	5.8	5.7	5.5	5.4	5.3	5.2	5.0	4.9	4.8	4.6	4.5	4.4
GDP growth (%)	7.8	8.2	8.0	7.9	7.7	7.6	7.4	7.2	7.1	6.9	6.8	6.6	6.4	6.3	6.1	6.0	5.8	5.6	5.5

Source: Deutsche Bank estimates

If the sector targets are achieved as we suggested in the PM2.5 reduction model, then the PM2.5 index will likely fall as illustrated in Figure 15 towards 30 by 2030:

Figure 15: Projection of PM2.5 under the reform scenario



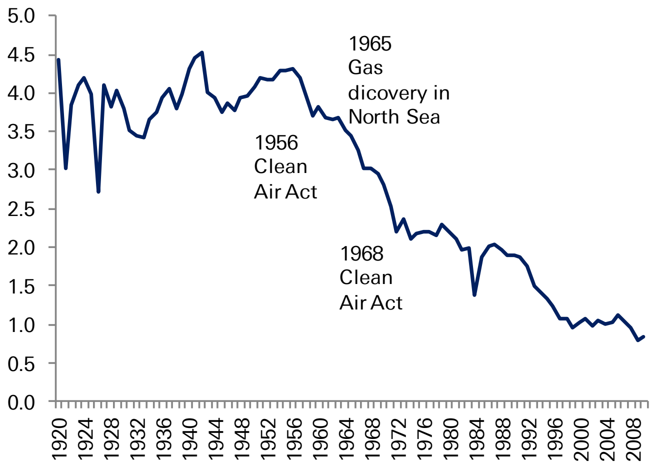
Source: Authors' PM2.5 forecast model; Deutsche Bank estimates

In the remainder of this chapter, we will discuss the details of the sector targets and the required policy actions to achieve these targets.

Coal consumption should peak in 2016

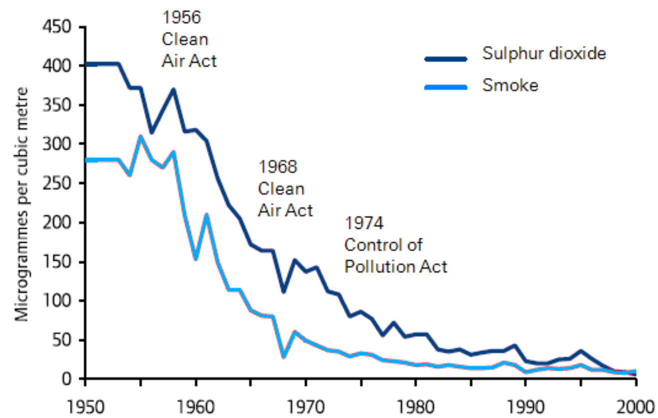
A key lesson from the UK, which experienced the "London Great Smog" due to serious air pollution in 1952, is that the rapid switch from coal to clean energy consumption (mainly gas) contributed greatly to the success in its pollution reduction in the subsequent decades (see Appendix B of this report for details). Figure 16 and Figure 17 show that between 1950 and 1970, per capita coal consumption fell by half in the UK, and air pollution measured by smoke and SO_2 also fell by more than half during the same period.

Figure 16: Coal consumption per capita UK (tonnes per capita)



Source: Deutsche Bank, Office of National Statistics UK, Department of Energy and Climate Change UK

Figure 17: Annual average smoke and sulphur dioxide concentrations in London 1950 to 2000



Source: Deutsche Bank, AEA Environmental Protection

Among these policy changes that we proposed for China, one of the most important but also most challenging tasks is to reduce coal consumption by 0.8% on an annual average basis in the coming 18 years. This is because even conservative expert projections for 2020 still imply a 2-3% annual growth rate of coal consumption, and most researchers and officials have not thought about the possibility of cutting coal consumption within next eight years. Figure 18 shows a comparison between our proposal and other projections so far. It shows that most forecasters (including those with government background) are expecting coal consumption to peak sometime between 2020 and 2030. Our new forecast of coal consumption peaking in 2016 is obviously the most aggressive outlier, but we believe it is achievable as long as policy makers take the public health impact of pollution serious enough.

Figure 18: Coal consumption targets: forecasts of peak year

Author/Source	Year of Peak Consumption
Our new projection (proposal)	**2016**
Our old projection	2020
International Energy Agency	2020
Hao Pengmei	2020
Alibaba	After 2020
Hu Angang et al	2025
Du Xiangwan	2030
Brad Plumer	2030

Source: Deutsche Bank estimates; IEA, World Energy Outlook; Hao Pengmei, 中国煤炭产业中长期发展趋势预测; Alibaba,com; Hu Angang et al, China 2030; Du Xiangwan, China Academy of Engineering; Brad Plumer, China now burning as much coal as the rest of the world combined

Of course, our 0.8% annual average reduction in coal consumption does not mean that the annual change from 2013-30 has to be the same every year. In the first few years of the projection period, as emissions related to coal burning can be reduced by a rapid increase in the desulphurization/denitration rate, the application of central heating systems as well as the use of cleaner coal, then coal consumption could still be allowed to grow modestly. Figure 19 shows our old forecast for coal consumption for the coming 18 years vs. our new projection (proposal) assuming more aggressive anti-pollution policies for 2013-30.

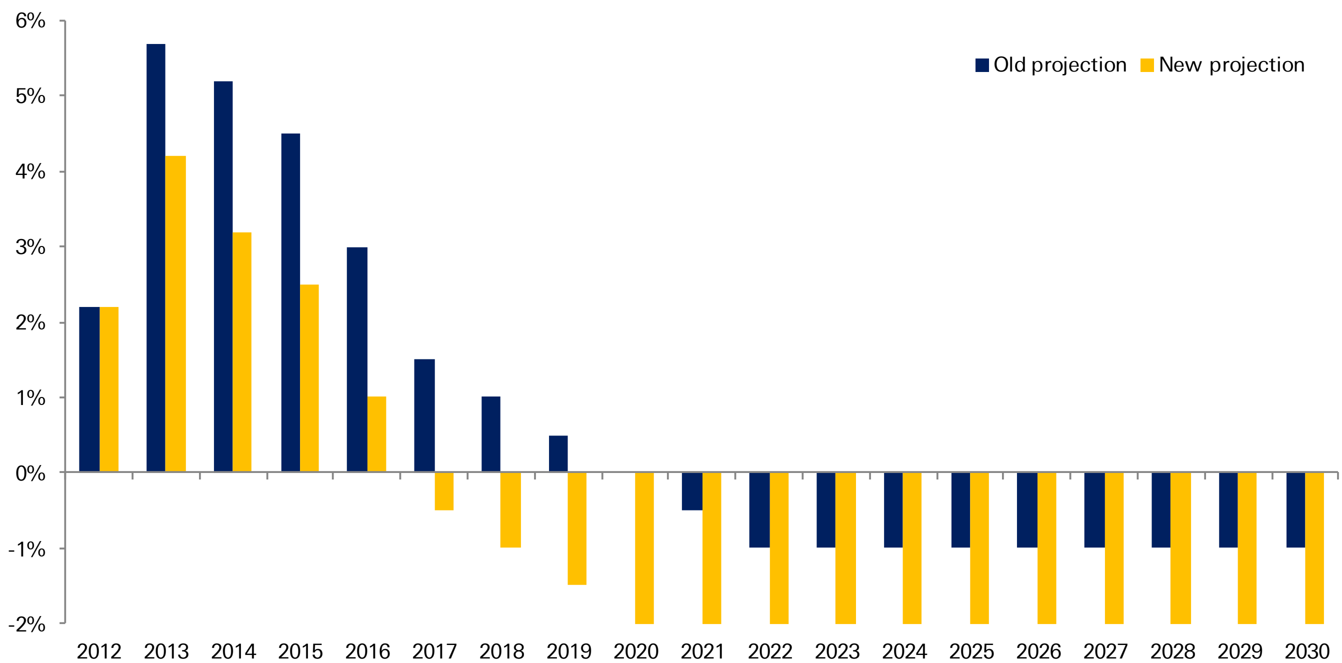
Figure 19: Coal consumption: old projection vs. new projection under aggressive anti-pollution policies

		2012	2013	2014	2015	2016	2017	2018	2019	2020	13-20 CAGR
Old projection		2.2%	5.7%	5.2%	4.5%	3.0%	1.5%	1.0%	0.5%	0.0%	2.7%
New projection		2.2%	4.2%	3.2%	2.5%	1.0%	-0.5%	-1.0%	-1.5%	-2.0%	0.7%

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	21-30 CAGR
Old projection	-0.5%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%
New projection	-2.0%	-2.0%	-2.0%	-2.0%	-2.0%	-2.0%	-2.0%	-2.0%	-2.0%	-2.0%	-2.0%

Source: Deutsche Bank estimates

Figure 20: China coal consumption growth: old vs. new forecasts



Source: Deutsche Bank estimates

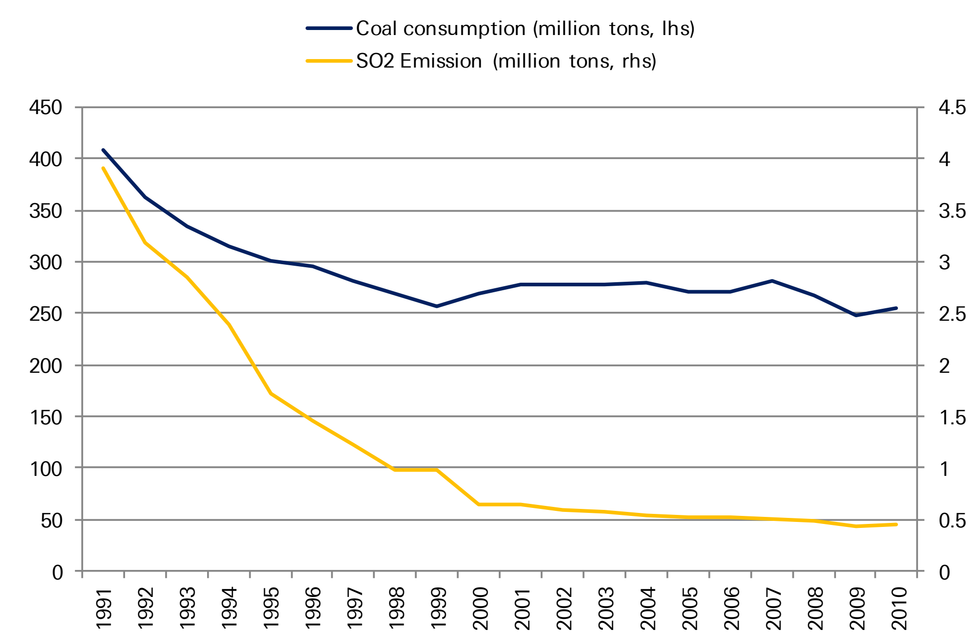
Emission per ton of coal consumption should fall by about 70%

As part of our PM2.5 emission reduction package, desulphurization and denitration in coal burning should accelerate to achieve a 6% annual average reduction in emissions in the coming 18 years, in order to reduce coal-related unit emission by 69% by 2030. This target should be achieved by: 1) higher installation and operation rates of desulphurization and denitration facilities; 2) closure of small, inefficient power plants; 3) industrial consolidation; and 4) more effective enforcement of regulations.

China has made some progress in SO_2 emission control during the past years. In 2011, 87% of power plants have installed desulphurization facilities. However, we believe the coal-emission control is far from perfect as desulphurization installation has yet to reach 100% for power plants, only 14% of plant plants have installed denitration facilities, and many power plants do not run these facilities even if they are installed. China will have to accelerate its pace in desulphurization, denitration and primary PM control during coal burning.

Germany has set an example for China in this field. From 1990-2010, with coal consumption falling by only 40%, Germany cut its SO_2 emission by 90% and NO_X by 55%. The desulphurization of thermal power plants took the lead, by cutting their annual SO_2 pollution from 2.4mn to only 0.1mn tons (Figure 21).

Figure 21: Germany's coal consumption vs. SO_2 emission

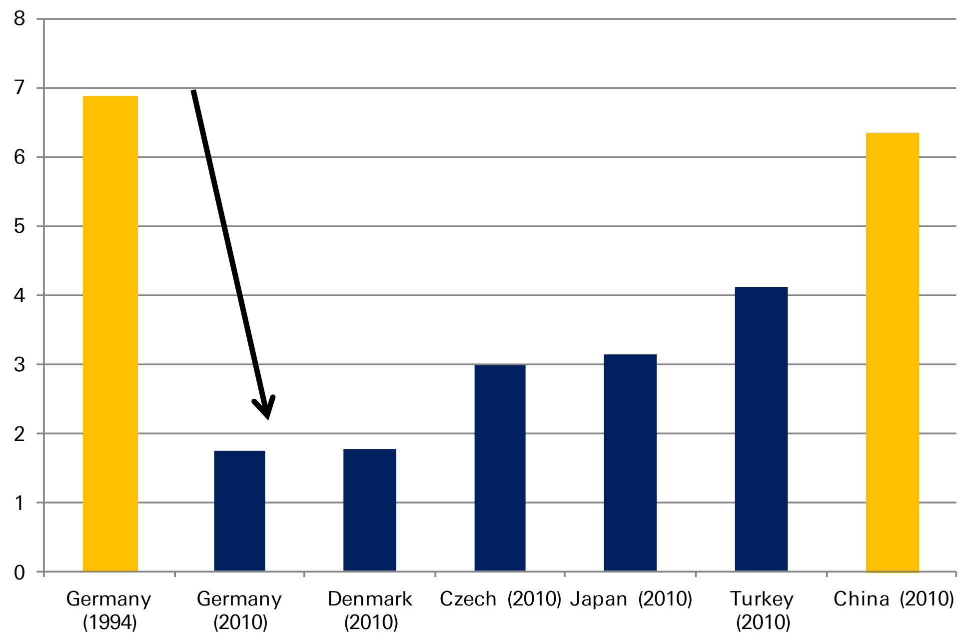


Source: OECD database, Deutsche Bank, US Energy Information Administration

In China today, despite the 87% desulphurization facilities installation rate, many power plants do not turn on these facilities in order to reduce costs. MEP data suggests that the operation rate is 95%, but anecdotal stories suggest a lower rate. Among all the operating facilities, the comprehensive desulphurization rate is only 73.2%. Official figures imply that only 64% (87%*73%) of sulphur emission by thermal power sector is controlled, while expert estimates are even less optimistic[15]. As a result, SO_2 emission per ton of coal consumption in China is as high as 6.3kg, equivalent to the level in Germany in 1994 and four times that of Germany today (Figure 22). Thus, China still has significant potential in desulphurization. We believe the total desulphurization rate should be raised by 6% per annum to reach 90%, resulting in a total sulfur-related reduction of 72% from its current level (i.e., reduction from 36% to 10%). The key measures to achieve this goal should include: 1) 100% installation of facilities; 2) 95%+ operation rate via stricter enforcement by environmental agencies; 3) a ban of flue gas bypass to result in a 90% comprehensive desulphurization rate of 90%.

[15] Project explanation document of Management technical specification of the operation of flue gas treatment facilities of thermal power plant

Figure 22: SO_2 emission (kg) per ton of coal consumption



Source: Deutsche Bank, OECD database

Beyond that, as NO_X emission from coal burning, which contributes to secondary particle formation, has doubled during the past 10 years, more attention should be paid to denitration. Given that the current installation rate of denitration facilities is merely 14%, we believe it should rise by at least 3ppts per year in the coming 18 years. The MEP should firstly ensure a 100% denitration facility installation in power plants with 200MW+ units and an effective rate of 85% by 2015. These requirements should be later applied to small and medium power plants. As for primary particle control, bag-filtering dust precipitator, a new technique which removes 80+% of direct PM emission during combustion, should also be applied more widely.

Moreover, as IPPs only account for 52% of total coal consumption in China, emission from other industrial sectors and households' coal usage should also be taken into account. For example, the cement sector alone emits 10% of the national NO_X and 5% of SO_2. We believe tougher regulations should be implemented regarding denitration in the sector. With the new Emission Standard of Air Pollutants for Cement Industry having come into force in January 2013, a comprehensive denitration rate of 50% should be reached prior to 2015 for plants with capacity above 4,000 tons/day. Similarly, fuel gas denitration facilities should be promoted in other industries, while central heating systems should be the major remedy for household coal burning.

Clean energies should rise to 27% of total energy consumption in 2030

In addition to the faster reduction in coal consumption and improvement in desulphurization/denitration, another important task in our newly proposed policy package is to further accelerate the growth of clean energy consumption. By clean energies, we refer to gas, nuclear, hydro, wind, and solar.

In this section we forecast the required clean energy consumption growth in the coming 18 years, based on the need to cut coal consumption by 0.8% on an annual average basis and to maintain annual average energy consumption growth of 3.4% per year. The assumption of 3.4% annual energy consumption is based on a real GDP growth target (6.8% annual average for the coming 18 years) and the energy elasticity to GDP growth of 0.5, which is broadly consistent with OECD countries' experience of (0.58)[16] and China's past five year average (0.53).

We show our new forecasts for fossil fuel and clean energy consumption growth in Figure 23 and Figure 24. While the energy mix change in our new forecast is more drastic than that in our old forecast (old forecast is done by our energy analysts, based on existing policies and sector trends). **In our new forecast, we expect clean energy consumption to rise from the current 13% of total energy consumption to 27% in 2020 and to 46% in 2030 (vs. the old forecasts of 19% in 2020 and 37% in 2030).** Compared with our old forecast, which projects a clean energy GAGR of 8% for 2013-20, our new projection shows a CAGR of 12%, 4ppts faster than the old forecast.

The latest government target announced in the 12th FYP is to enhance the total share of non-fossil fuels energies (wind, solar, nuclear and hydro) as % of primary energy to 15% by 2020. This is broadly consistent with our forecast of the total contribution from these four clean energy sources for 2020. The major upside potential to the current government projection is from natural gas.

Figure 23: Our new projection of China's energy consumption mix, 2020

	Current (2012)	New forecast	Old forecast	Revision (ppts)	Implied CAGR 12-20 (old)	Implied CAGR 12-20 (new)
Coal	68.4%	52.8%	61.5%	-8.7	2.6%	0.9%
Oil	18.6%	20.0%	19.5%	0.5	4.4%	4.7%
Wind	0.7%	2.5%	1.2%	1.3	10.5%	19.9%
Solar	0.02%	0.4%	0.2%	0.2	31.8%	42.3%
Gas	5.0%	12.0%	8.5%	3.5	10.1%	14.4%
Nuclear	0.8%	3.2%	2.0%	1.2	14.8%	21.0%
Hydro	6.5%	9.2%	7.2%	2.0	5.0%	7.9%
Clean energies*	13.0%	27.3%	19.1%	8.2	7.9%	11.9%
Total	100%	100%	100%			

Source: Deutsche Bank estimates; Note: clean energies include gas, wind, hydro, solar and nuclear.

Figure 24: Our new projection of China's energy consumption mix, 2030

	Current (2012)	New forecast	Old forecast	Revision (ppts)	Implied CAGR 12-30 (old)	Implied CAGR 12-30 (new)
Coal	68.4%	31.8%	41.2%	-9.4	0.7%	-0.6%
Oil	18.6%	22.4%	22.1%	0.3	4.4%	4.5%
Wind	0.7%	5.1%	3.6%	1.5	12.9%	15.0%
Solar	0.02%	3.1%	1.8%	1.3	30.0%	33.8%
Gas	5.0%	18.0%	14.2%	3.8	9.3%	10.7%
Nuclear	0.8%	8.0%	7.0%	1.0	15.9%	16.7%
Hydro	6.5%	11.5%	10.0%	1.5	5.8%	6.6%
Clean energies*	13.0%	45.7%	36.6%	9.1	8.2%	9.3%
Total	100%	100%	100%			

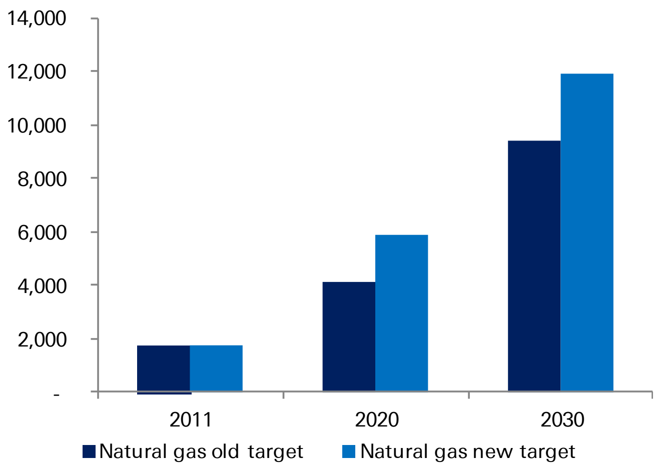
Source: Deutsche Bank estimates; Note: clean energies include gas, wind, hydro, solar and nuclear.

We revised the target for natural gas annual average growth to 14% from current 10% from now to 2020. By 2020, we expect gas to reach 12% of primary energy consumption. By the end of 2030, we expect it to rise to 18% of the primary energy consumption. Solar power, which is less than 0.1% of current energy composition, will

[16] The elasticity is calculated based on 34 OECD countries' historical data from 1986-2005.

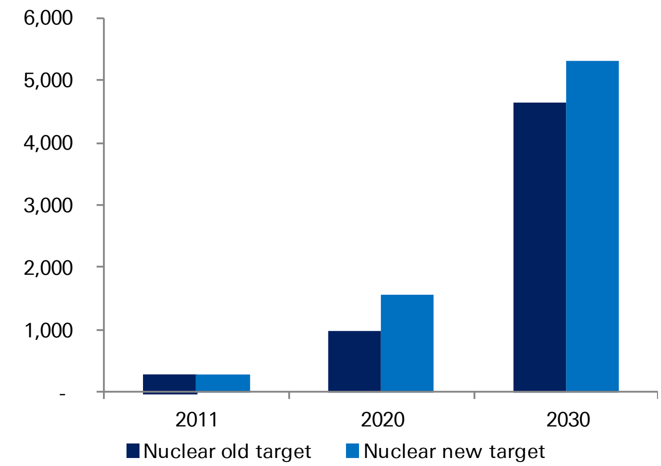
reach 3% by 2030, according to our new forecast. This target implies an average growth rate of 34% in the coming 18 years. We also revised up our forecast of annual average growth of wind and nuclear from 13% to 15% and from 16% to 17%, respectively, for 2013-30. As for hydro power, we forecast a modest annual average growth rate of 6.6% due to its environmental impact and constraint of total water resources (Figures 25-29).

Figure 25: Natural gas annual consumption (million tons standard coal): old target versus new target



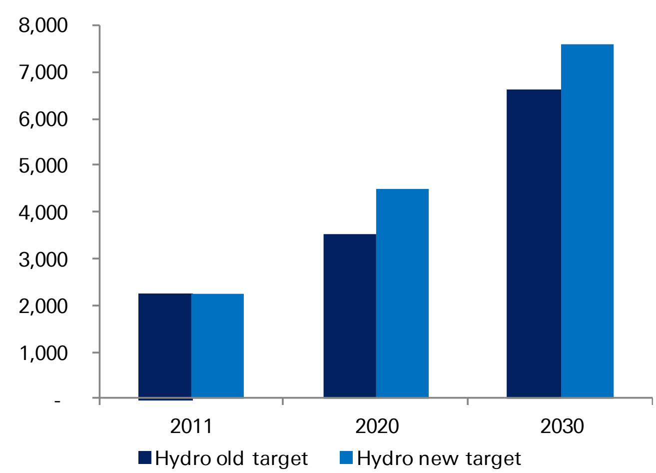
Source: Deutsche Bank, NBS

Figure 26: Nuclear power annual consumption (million tons standard coal): old target versus new target



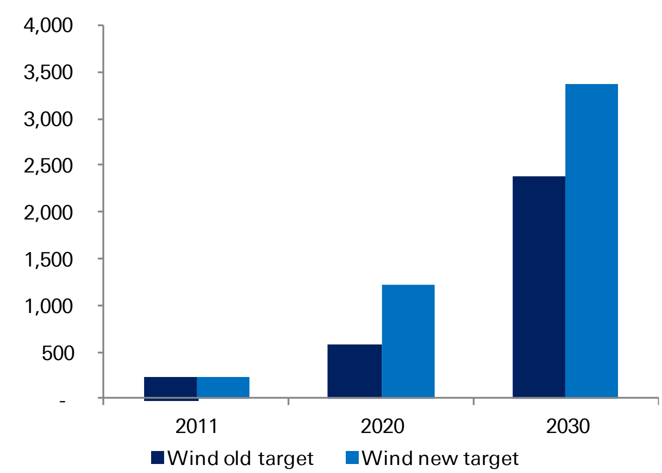
Source: Deutsche Bank, NBS

Figure 27: Hydro power annual consumption (million tons standard coal): old target versus new target



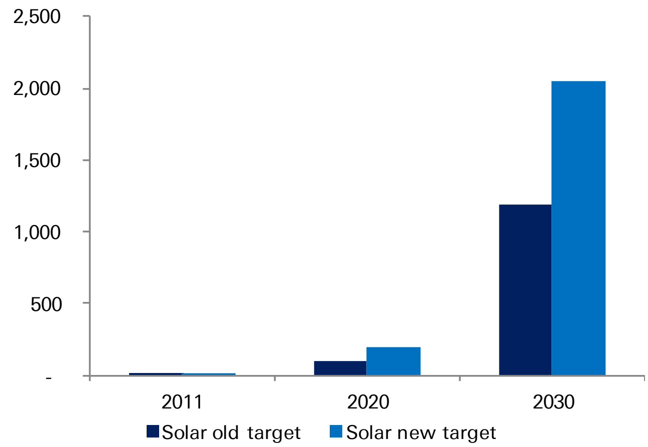
Source: Deutsche Bank, NBS

Figure 28: Wind power annual consumption (million tons standard coal): old target versus new target



Source: Deutsche Bank, NBS

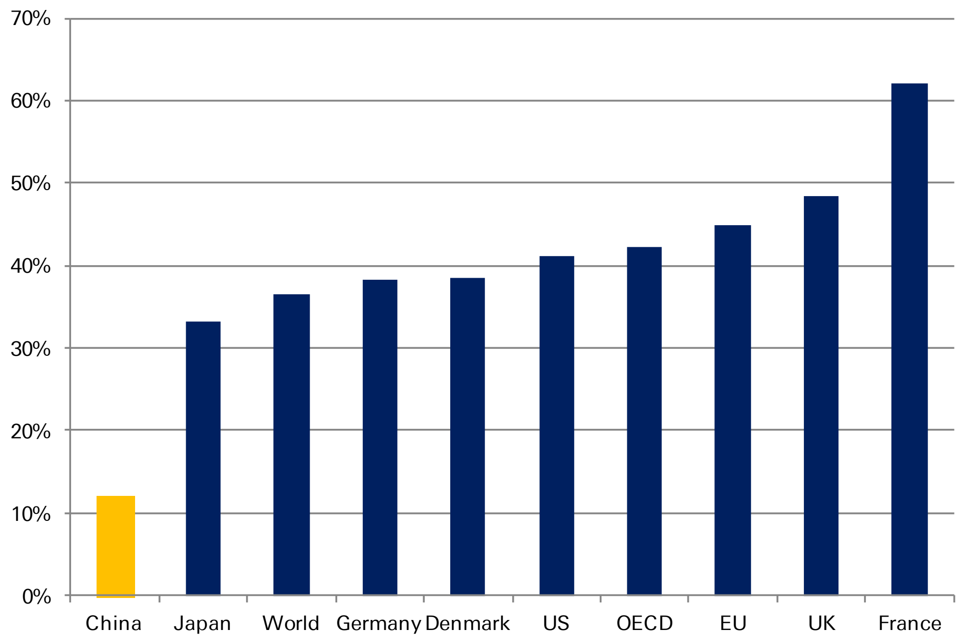
Figure 29: Solar power annual consumption (million tons standard coal): old target versus new target



Source: Deutsche Bank, NBS

The immediate reaction from many readers to our seemingly aggressive projection of the energy mix change is "whether it is technically feasible". We will discuss the technical feasibility of each individual alternative energy source in detail later, but at the aggregate level, it is useful to look at what has already been achieved in OECD countries. Figure 30 below shows that in 2010/11 clean energies (including gas, nuclear, wind, solar and hydro) already reached 42% of total energy consumption in OECD countries on average, vs. only 13% in China. Note that in France, this ratio has reached 62%. The vast cross-country difference in the ratio of clean energy contribution simply suggests that political will and the accompanying fiscal spending are the single most important factor in determining a country's progress in clean energy development, while technology is not a major obstacle. Given these success stories, the discovery of more natural gas, shale gas and CBM resources in China, as well as the ongoing technology advancement in reducing the costs and improving the stability of wind and solar power, we believe it is reasonable to expect China's clean energy to rise to 27% of total energy consumption in 2020 and to 46% in 2030.

Figure 30: Clean energies as % of total energy consumption reached 42% already in OECD countries



Source: Deutsche Bank, Statistical Review of World Energy 2012

Gas

We believe that natural gas provides the biggest upside in terms of its potential increase in clean energy contribution to China's energy mix. China's 12th Five-Year Plan for Natural Gas Development aims at an annual gas consumption of 230 billion cubic meters (bcm), implying a 15% CAGR during 2011-2015 from the 2011 level of 130bcm. This near-term target, largely in line with our new forecast, is feasible in our view.

For the medium-term and longer run, China's natural gas production will be increasingly driven by unconventional gas. According to the 2010 evaluation of oil and gas resources, China's recoverable conventional gas reserve is estimated to have reached 32tr cm (tcm), while CBM recoverable reserve (at depths of less than 2,000 meters) and technically recoverable shale gas amount to 10.8tcm and 25.1tcm. These vast reserves, especially those of unconventional gases, which are 1.6 times the conventional one, suggest a potential "high gas scenario" for China. According to US Department of Energy and EIA data, China has the largest shale gas reserves in the world. NDRC has set goals of 6.5bcm and 16bcm for CBM and shale gas production by 2015. While those numbers are small compared with total gas consumption, we believe these unconventional energy sources will likely become the growing poles for future clean energy strategy in the next 3-8 years.

The government together with the private sector will invest heavily in R&D, exploration, production, pipelines and infrastructure. China has held in June 2011 and October 2012 two rounds of shale gas block auctions, in which the exploration right of 23 blocks have been handed over to successful bidders, with a total shale gas reserve of 20+ trillion cubic meters. In the second round bidding especially, both non-state owned Chinese entities and Sino-foreign joint ventures were encouraged to participate in the bidding. The third round of auction is expected to start in H2 this year, which will likely include more resource-rich blocks in Northern part of China, according to press reports. This shows the government's determination to open up the shale gas business to a wider group of players. In addition, the Ministry of Finance announced last November a special project fund to subsidy companies conducting shale gas exploitation. The subsidiary standard is RMB0.4 per m^3 from 2012 to 2015.

Given the favorable policies, enterprises are in action. China Shenhua (1088.HK), for instance, plans to invest RMB50bn in Guizhou in the years up to 2020, with technical support and equipment supply from Honghua (0196.HK), the largest exporter of oil-drilling equipment in China. Others have resorted to international collaboration: PetroChina (0857.HK) has agreed with Conocophillipes (COP.NY, a US company) to conduct joint research and investment in Sichuan shale gas blocks. Pure domestic players have also manifested their local expertise: Guizhou Wujiang Hydropower Development is to invest RMB12bn (USD$1.9 billion) in developing three to five local shale gas exploration zones within the next five years, aiming at large-scale production of 600mcm annual output in five years time.

As for national transportation network, West-East, Sichuan-East, Shaanxi-Beijing and coastal pipelines will be established in the next few years. 18% of urban population (250 million people) will have access to household gas by then. Compressed natural gas (CNG) programs to replace petrol or diesel will be expanded to more cities (already available in Beijing and some western provinces) and more subsidies will also go to the transportation sector to encourage buses and taxis to run on gas.

Some are concerned about the potential environmental impact of shale gas development, with worries including 1) exacerbated water shortage by extensive drilling; 2) ground water contamination by drilling fluids; 3) inadequate liquid waste disposal[17]. In light of international experiences, we believe that these risks are controllable.

A US empirical study[18] has shown that the total volume of water required for shale gas production in a shale basin range from 0.1% to 0.8% of total water use in the region. Pennsylvania, one of the major shale gas regions in the US, consumers 3.6 trillion gallons of water annually, among which the shale gas industry withdrawals only account for about 0.19%. In terms of contamination control and sewage treatment, the MIT 2011 Gas Report[19] pointed out that there were only 43 "widely reported" contamination incidents related to gas well drilling from 2000-2010 during which time, there were about 20,000 shale gas wells drilled with almost all of them being hydraulically fractured. The report concluded that that "the environmental record of shale gas development has for the most part been a good one….In the studies surveyed, no incidents are reported which conclusively demonstrate contamination of shallow water zones with fracture fluids." Despite the existing problems, we believe that together with the further advancement in technologies and the monitoring systems, the aforementioned risks can be better managed in the future.

The main benefit of developing natural gas is that its consumption generates much lower particulate emissions than coal and oil. The NDRC has suggested that, with the 2015 NDRC target achieved, the increased 120bcm natural gas consumption from 2010 will mitigate annual SO_2 emissions by 5.8 million tons[20], equivalent to 28% of current national SO_2 emissions. From the perspective of car emissions, a Tsinghua University study has shown that buses fueled by natural gas emit only 0.005g of PM2.5 per kilometer drive, a 93% reduction compared to National IV diesel fuel standard[21] (Figure 31).

---

[17] Accenture, Water and shale gas development, 2012

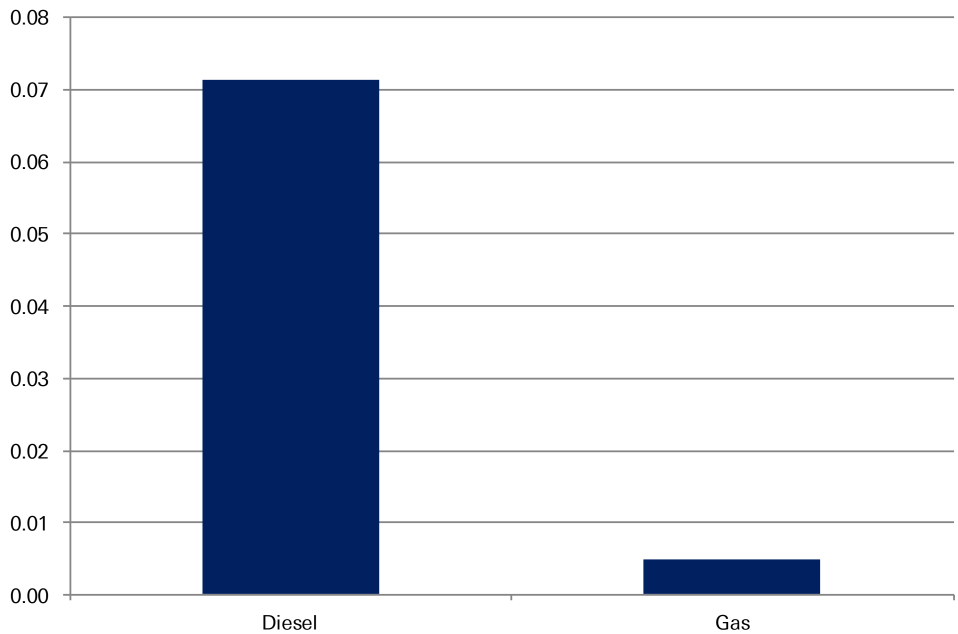
[18] US Department of Energy, Modern Shale Gas Development in the United States: A Primer, April 2011

[19] The Future of Natural Gas, MIT, 2011, web.mit.edu

[20] Natural Gas Development 12th Five-Year Plan, NDRC, China

[21] Tsinghua University & NDRC, The Vehicle Pollution Control in China, 2001

Figure 31: PM2.5 emission by bus fueled by natural gas and diesel (g/km drive)



Source: School of Environment, Tsinghua University

Nuclear

Nuclear power provides 15% of the world's electricity, but its proportion stands as low as 1.9% in China. The development of nuclear energy is largely determined by central government policies. The original target set by the 12th Five-Year Plan was to quadruple the 2010 capacity of 10.8GW to reach 40GW within 5 years, a plan which implies a 2020 target of 80GW according to some analysts. However, China has slowed its pace in constructing new nuclear plants after the Fukushima accident due to safety considerations. Despite this tentative setback, we still forecast a double-digit CAGR for the industry, as 1) the country will be hungry for clean energies in the coming years as many other alternative resources like solar and wind are too small in size to make a meaningful contribution to the change in energy mix, 2) China has adopted the safest third generation nuclear technology (AP1000) as a standard for inland nuclear projects, and has already built four AP1000 nuclear generators. We believe China's nuclear power can make up 3.2% of total energy mix by 2020 (a slight downward revision from the 80GW target).

Hydro

The latest national survey of hydro resources in 2005 indicates that China's gross theoretical hydropower capacity potential is about 694GW. Therefore, we believe that hydro power, which currently provides 6.5% of the country's primary energy consumption, has the potential to double its 2010 capacity of 213GW before 2020. The National Energy Administration gives similar estimates, forecasting a total installed hydropower capacity of 420GW in 2020. For the period from 2020 to 2030, we forecast a relatively modest annual growth rate of 6.5%, taking into account the environmental controversies.

Wind

By 2020, the cumulative grid-connected wind power capacity will reach 200GW (up from 45GW of 2011), and the annual generated energy will surpass 390bn kWh, according to the NDRC. This target translates into 2% of total primary energy consumption, broadly in line with our new forecast. Moreover, China's Energy Research Institute (ERI) of the NDRC gives a long-term capacity roadmap of 400GW by 2030, which implies a similar CAGR to our forecast. As the country's wind power potential is estimated to be between 2TW and 3.4TW by the Fourth Wind Survey conducted by China Meteorological Administration, we believe that these targets are achievable by strengthening priority grid access, amelioration of power distribution and transmission, establishing a market-based power pricing system as well as development of offshore wind power. Currently, offshore wind is still in its pilot stage, with technologies relatively mature for water depths of 5m to 25m and being developed for depths of 25m to 50m. ERI research indicates that China's exploitable potential of offshore wind source (water depths 5m-25m) is 500GW[22], suggesting that a 30GW target (2020) set by the 12th Five-Year Plan Alternative Energy is feasible.

Solar

The 12th Five-Year Plan projects an installed solar power capacity of 50GW by 2020, up from the 2010 level of less than 0.86GW, which implies a CAGR of 50% between 2010 and 2020. Our new forecast, which expects a CAGR of 42% from 2013-20, is less aggressive, taking into account the required fiscal subsidies (much higher than on wind per Kwh). To achieve our forecast, the government still needs to provide strong incentives for private sector investment.

In conclusion, we believe that our new forecast of clean energy growth in the coming few years is broadly consistent with relevant government agencies and specialists' forecasts, and our longer-term forecasts are technically feasible and supported by China's available resources. The key question is whether the government will demonstrate strong enough willingness and allocate sufficient fiscal incentives to support the development of these industries.

Emission per KM driven on road should fall by about 80%

Although we expect new policies (e.g. via introduction of a car license plate auction system) to slow the growth of car consumption growth, private vehicle (PV) possession will still be 250mn in 2030, 2.8 times the current level. The total number of on-road vehicles including PVs, trucks and buses will likely reach 290mn by 2030. In order to reduce PM2.5 from road transport, China will have to implement stricter (namely moving from National III to National V) fuel standards for petrol (both gasoline and diesel) and for car emissions. We estimate that the full implementation of the National V standards will cut emissions per car by an average of about 78% from its current level. This, together with a 20% increase in fuel efficiency[23] and a 22% reduction in car usage rate (KM driven per car)[24], imply that total road emissions could fall by 64% in 2030 from the current level, even with an increase in the number of PVs by 180%. Emission per KM driven on road should fall by 82% as a result of the 78% reduction in emission by higher fuel and emission standards and the 20% improvement in fuel efficiency.

Upgrading fuel standard to National V

PM emissions are directly related to the fuel sulfur content. During combustion, sulfur in fuel converts into direct PM emissions and SO_2 emissions that can lead to secondary particle formation, regardless of car emission control. Therefore, a reduction in sulfur in fuel can result in lower PM.

[22] International Energy Agency & China Energy Research Institute, Technology Roadmap China Wind Energy Development Roadmap 2050

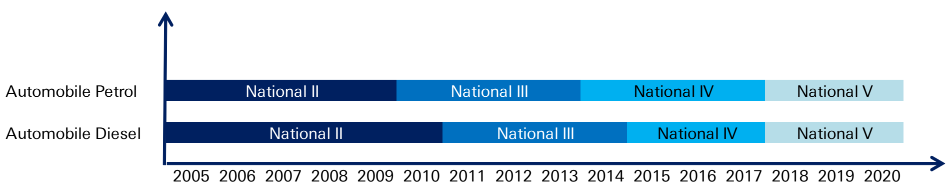
[23] In the past 20 years, fuel efficiency in European countries rose by 15-20%.

[24] See footnote 15.

China's National IV standard for automobile gasoline requires sulphur content to be no more than 50ppm (parts per million). However, only some developed regions, including Shanghai, Guangdong, Jiangsu, and Zhejiang, adopted the National IV standard, while other regions still adopt the National III standard, which allows sulphur content of as high as 150ppm. Beijing is the only city to adopt the National V standard this year, which is equivalent to the Euro V standard in terms of sulphur content (below 10ppm).

On February 6, the State Council issued a timetable to upgrade fuel quality. According to this timetable, the General Administration of Quality Supervision and the Inspection and Quarantine and the Standardization Administration will issue the National V standard for automobile petrol, with sulphur content within 10ppm, before the end of 2013. The National IV standard for automobile diesel, with sulphur content within 50ppm, will also be issued and the transition time will expire at the end of 2014. By the end of June 2013, National V standard for automobile diesel, with sulphur content within 10ppm, will be issued. The transition period of National V standard of both petro and diesel is before the end of 2017 (Figure 32).

Figure 32: Timetable for implementing National V standard for petrol and diesel



Source: China's Standard Administration

Upgrading car emission standard to National V

Even after petrol and diesel have met the National V fuel standard in 2017, it will take a number of years for all vehicles to reach their National V emission standards, as the replacement of old, compliant cars will take longer. We expect 2022 as a likely date by which all vehicles will meet the National V requirement. We believe this timeline is technically achievable, based on international experience. In European countries, it took 4-5 years to complete the upgrade from Euro III to Euro IV and another 3-4 years from IV to V emission standard.

Given these timetables, we estimate that emission per vehicle could be reduced by 78% from current levels due to higher fuel quality and emission standards. This estimate is justified by a combined reduction from both passenger cars and commercial vehicles. In 2011, national air pollution related to mobile sources was 46mn tons. Apart from 35mn tons of CO (non-PM contributor), other PM-related emissions compromise 5% of direct PM, 55% of HC and 37% of NO_X. Both NO_X and HC in exhaust fumes also turn into secondary PM2.5 in the air. We also know from the MEP Annual Report on mobile pollution that passenger cars account for 70% of HC, 30% of NO_X and less than 10% of direct PM, while diesel burning vehicles emit 90% of direct PM, 70% of NO_X and 30% of HC.

Based on the National III, IV, and V Emission Limits Regulations on cars (Figure 33), we estimate that a weighted average reduction rate of total pollution from National III to National V will be about 60% (NO_X 63%, HC 50% and direct PM 99%). Experts and officials hold similar opinions.[25] In addition, China still has 46% National II or even lower

[25] According to Cai Zhigang of Shanghai Environmental Protection Bureau, an upgrade from National IV to National V for both cars and gasoline can reduce emissions by 50% (http://news.xinhuanet.com/fortune/2013-

standard vehicles on the road, which implies that the emission reduction could be even more significant if the government requires these old cars must be scrapped. We therefore estimate that an upgrade to National V for both fuel and car emission standards could reduce emissions per car by about 78%. Also, if the government introduces new incentives for purchasing low-emission vehicles with better fuel efficiency and electric cars, emissions could be reduced further.

Figure 33: Limits and standards: reduction due to change from National III to IV

		National III	National IV	National V	Reduction from III to V
Petrol vehicle	CO (g/km)	2.3	1.0	1.0	-57%
	HC (g/km)	0.2	0.1	0.1	-50%
	NO_X (g/km)	0.15	0.08	0.06	-60%
Diesel	CO (g/km)	0.64	0.50	0.50	-22%
	NO_X (g/km)	0.50	0.25	0.18	-64%
	Direct PM (g/km)	0.50	0.025	0.0045	-99%

Source: MEP, Deutsche Bank

As for efforts to be made by industries, some automobile producers need to upgrade technologies to produce cars that meet the National V emission standard. Most JV producers have no problem in meeting the standard as they are already producing using the Euro V standard. But many local producers will have to catch up. In terms of oil refining, China's two largest refiners, Sinopec and PetroChina, own nearly 80% of China's refining capacity. They need to upgrade their refining equipment to produce higher standard fuel.

Limit the number of passenger cars to 250mn by 2030

Our policy package for PM2.5 reduction requires a 50% decline in transport-related emissions by 2030. This 50% should be decomposed into several sources: a slowdown in car traffic growth, a 78% reduction in car emission via higher fuel quality and car emission standards, a 20% increase in fuel efficiency, and faster growth of the much less polluting railway/subway traffic (at 7.1% p.a. vs. overall traffic growth of 5.5%). Given the parameters mentioned above, it implies that road traffic growth needs to be controlled at an annual average rate of 4%. Assuming that the car usage rate will decline by 22% in the coming 18 years[26], this 4% annual average road traffic growth implies that the number of passenger vehicles (PVs) should grow from the current 90mn to about 250mn in 2030.

While the government does not have an official target for car ownership growth, many sector experts expect the total number of PVs in China to rise to about 400mn by 2030[27] and one economist has even forecast a peak number of 750mn units. Their argument is that even with 400mn cars, China's PV penetration (defined as the number of PVs per 1000 people) will remain as low as 28%, far lower than 63% in the US and about 46% in OECD countries.

02/06/c_114636514.htm). According to a spokesperson of the Technology Standard Department of the MEP, the full implementation of National V standard can reduce NOX by 25-28% and particulates by 82% from the current levels.

[26] In the past 20 years, the KM driven per car has declined by 10-15% in major European countries. This is because that the development of the public transport systems allows people to commute more cheaply and conveniently with subways and railways. Therefore, car traffic growth tends to grow at a slower pace than car ownership. We believe that China should adopt a more aggressive policy to develop its public transport system and as a result the KM driven per car can slow even more quickly than in Europe. See http://www.economist.com.hk/node/21563280

[27]Prof Zhang Xiliang, Director of Energy and Environmental Research Institute at Tsinghua University, estimates that China's PV ownership will reach 400mn (http://www.chexun.com/2012-12-13/101632253.html).The" estimates from China Vehicle Energy Research Institute of Tsinghua University range from 380mn to 480mn in 2030 (http://qhxb.lib.tsinghua.edu.cn/oa/darticle.aspx?type=view&id=20110626).

Our PM2.5 model shows, however, that China's environmental capacity cannot accommodate 400mn passenger vehicles by 2030. We calculation shows that, in order to reduce the urban average PM2.5 at 30 by 2030, and with maximum efforts in the reduction in coal-related emission and emission per car, the total number of passenger cars will still need to be capped at 250mn by 2030. This means that the annual average growth of PV sales will be about 5% from 2013-30, down from 20% p.a. in the past five years (2007-12).

Our suggested target implies that China's car penetration will be capped at about 18% in 2030. This is feasible, as long as China significantly increases its investment in railway and subway systems, and introduce sufficient disincentives for car consumption growth (see below discussion on car license plate auction).

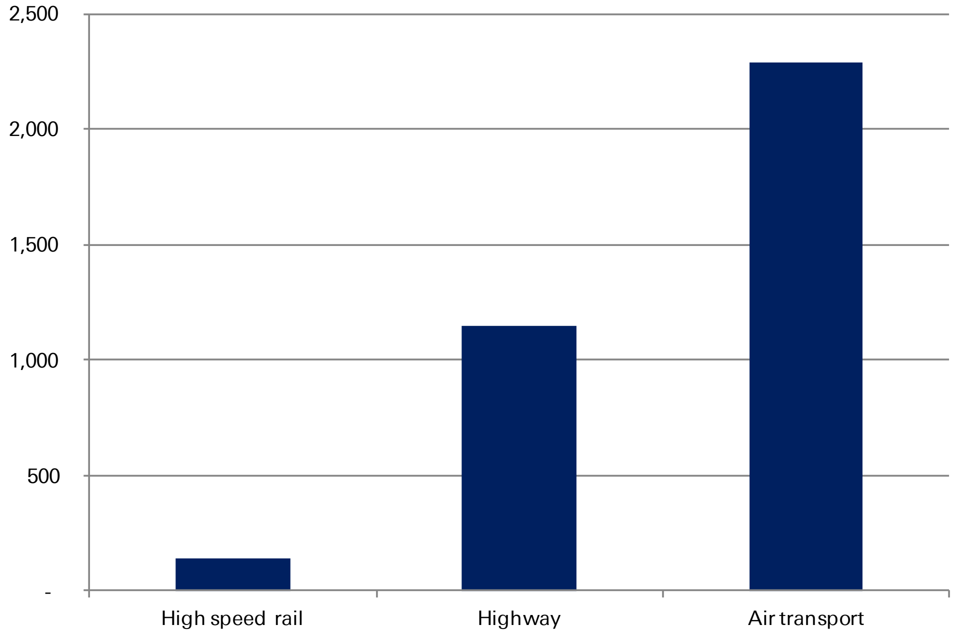
Many would argue that an 18% PV penetration rate is too low relative to China's development level in 2030 based on international experience. We disagree. Our calculation shows that China in 2030 will have a per capita GDP (in 2000 constant USD) of about USD 9,357, based on 6.8% annual average GDP growth in the coming 18 years. This is similar to the per capita GDP level (also measured in 2000 constant USD) in most OECD countries in early 1970s, when the passenger car penetration rate was on average about 19%. In addition, one should not compare China with the US where population density is much lower (than China and Europe) and energy policy has encouraged excessive fuel consumption.

Beyond 2030, we believe that China's PV penetration could grow further and eventually peak at 40-50% in 2050-60. At a 40% penetration rate, China's PV ownership will reach 600mn cars. This is possible as clean energy technologies could be so developed then that car-related emissions will be much lower than we can imagine today.

Increase railway length by about 60% from 2013-20

Relative to road and air transport, railway transport is a much less pollutant mode. For example, in terms of energy-related emissions, high speed rail only represents between 1/10 and 1/20 of that from highways and air travel. Figure 34 shows the energy consumption comparison between the three transport modes:

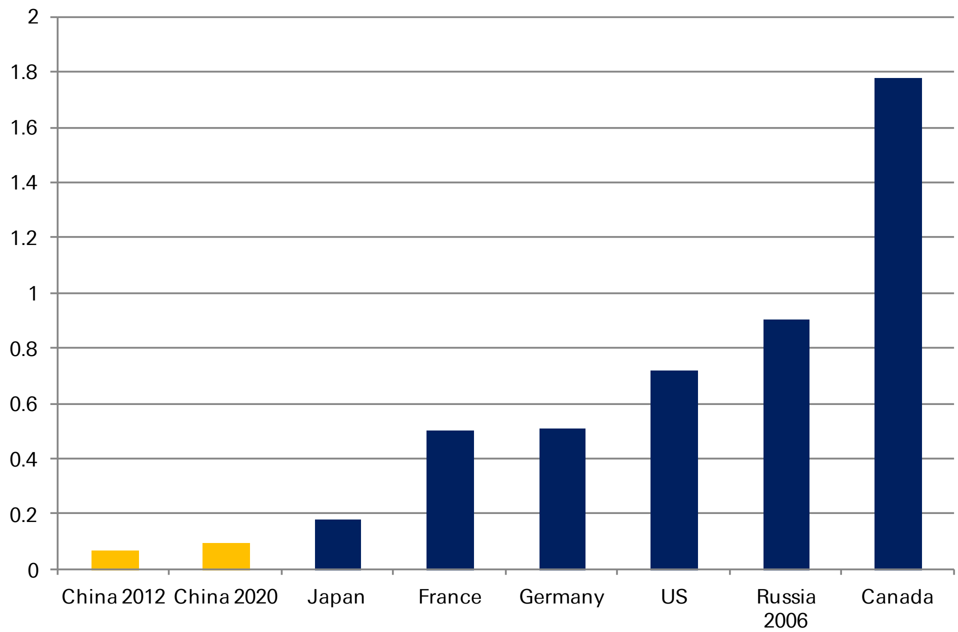
Figure 34: Comparison of energy consumption by transport mode (fuel consumption per passenger km by conventional railway = 100)



Source: Zheng Qipu, "Beijing-Shanghai High Speed Railway and Environmental Impact", Journal of Railway Engineering Society, March 1998. http://wenku.baidu.com/view/5d3520d5b14e852458fb57ed.html

However, the current government plan for building railways remains too conservative in our view, as it has been hampered in part by the railway accident in Wenzhou two years ago and the financing difficulties facing the Ministry of Railway. The current government plan is to increase the total length of railways to 120,000km by 2015, up from 90,000km in 2011. For 2020, there is no official target, but the current trend suggests a likely target of 140,000km, based on out discussion with experts within the government. This means that, even by 2020, China's railway density (measured by total length per 1000 persons) will remain only 1/8 of major OECD countries' average (Figure 35).

Figure 35: Railway density (km per 1,000 persons)



Source: Deutsche Bank, China Railway Yearbook.

Our calculation, based on a top-down approach that translates the emission reduction target to the increase in public transport traffic, shows that railway/subway traffic (of which 95% is railway traffic) needs to grow at 7.1% p.a. if road traffic growth is to be controlled at about 4% per annum. Assuming a railway traffic elasticity to railway length of 1.2[28], it requires an increase in the total length of railways by 165% from 2013-30 (Figure 36). This implies that the total length will have to rise by about 5.5% per year during this period, reaching 255,000km by 2030 (Figure 36). For 2013-20, we expect higher annual average growth rate (due to lower base and relatively strong traffic growth compared with 2020-30). This results in a railway length target of 160,000km for 2020, 63% higher than the length in 2012 (98,000km) and 15% higher than the current forecast for 2020 (140,000km). For details, please refer toFigure 37.

If this forecast materializes, China's railway density will rise to 0.18km per 1,000 people in 2030, about 1/4 of that in major OECD countries.

---

[28] This elasticity reflects the increase in efficiency, including from the higher percentage of double tracks, higher dispatch frequency, etc.

Figure 36: Decomposing traffic growth to road and railway/subway, annual average 2013-30

GDP growth	**6.8%**
Traffic growth	5.5%
Road traffic growth	4.0%
Railway/subway traffic growth	7.1%
Railway traffic growth	6.6%
Subway traffic growth	17.0%
Railway length growth	5.5%

Source: Deutsche Bank estimates

Figure 37: Old vs. new growth forecasts for total length of railways

	Old forecast	New forecast
Growth from 2013-20	43%	63%
Length in 2020 (1,000km)	140	160
Growth from 2020-30*	27%	65%
Length in 2030 (1,000km)	178	255

Source: Deutsche Bank estimates

Increase subway length fourfold by 2020

The government's plan is to increase the total length of subways and light rails (hereafter subways for simplicity) to 7,000km by 2020, up from the current 2,000km. However, we believe that this target is too modest, and is inconsistent with the required reduction in car exhaust emissions in cities. Based on our PM2.5 forecast model, we suggest that the total subway length target be raised by about 40% to 10,000km (from the current target of 7,000km) in 2020. This means a four-fold increase between now and 2020. From 2021-2030, the total subway length should be further increased to around 33,000km by 2030, in order to accommodate the required reduction in the growth of road traffic in urban areas.

Based on data from Beijing, Shanghai and Wuhan, we estimate that the current composition of transport mode in Chinese cities is roughly: 46% by private cars and taxies, 7% by subways and light rails, and 47% by buses. This implies that if traffic by private cars can only grow 4% per year (needed for PM2.5 reduction), then urban public transport has to grow 9% per year in order to satisfy the need to grow overall traffic by 6% per year (a slightly higher rate than the 5.5% for the country as a whole, considering the urbanization trend). Given that energy efficiency and energy-related emissions are much lower for subways than for vehicles on the road, as well as the speed advantages of subways, we believe that subway transport (total passenger km) should grow at 17% p.a. vs. 6% p.a. for buses between 2013 and 2030. Note that this 17% annual average growth will bring China's subway density (subway length as % of urban population) to about 75% of the current average of developed cities in the world.

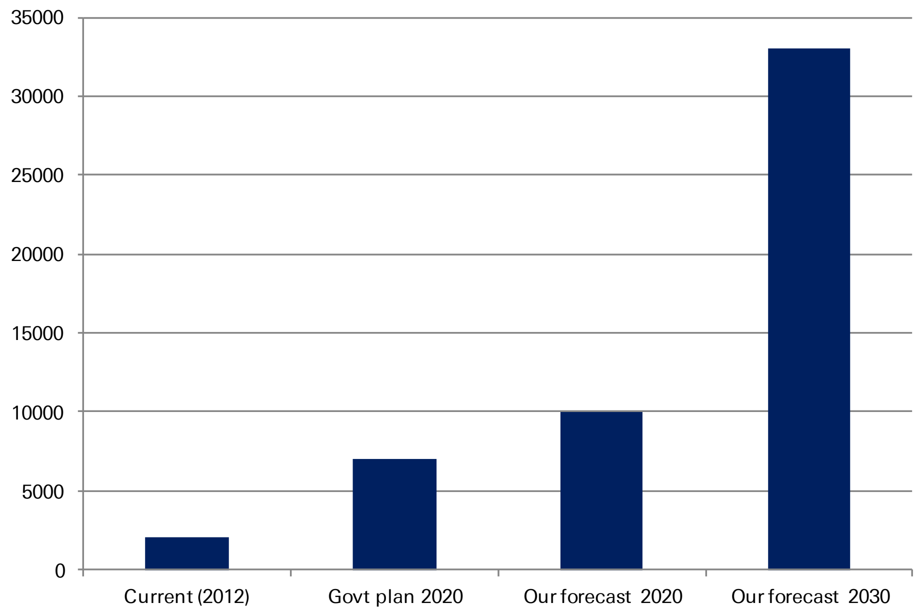
Given this 17% annual average growth in next 18 years, and assuming the growth of the subway length is higher (at 22% p.a.) from 2013-20 and lower (13% p.a. due to a larger base) from 2020-30, it implies that the total length of subways will need to rise to around 10,000km by 2020 (five times the current length), and to 33,000km by 2020. In other words, the current target for the 2020 subway length should be raised by about 40%, and it should grow another 230% from 2020-30 (Figures 40-41).

Figure 38: Forecast of traffic growth by transport mode in cities, 2013-30

	2012	2013-30	2030
	Weight	CAGR	Weight
Cars/taxies	46%	4.0%	26%
Buses	47%	6.5%	41%
Subways	7%	17.0%	33%

Source: Deutsche Bank estimates

Figure 39: Total length of subways: government plan vs our forecasts (km)



Source: Deutsche Bank, China City Rail Transit Association

Changing incentives via policy reforms

The above discussion focused on the need for a faster shift in the energy mix and higher usage of the public transit system. In this section, we will discuss another fundamental issue: how to incentivize firms and consumers to reduce or slow the growth of coal and auto consumption, switch more quickly to alternative energies, and chose to travel more with the public transit systems.

Firms and consumers make decisions on the types of energies largely based on prices. Therefore, it is of paramount importance to correct the ongoing distortions in the energy and environmental pricing systems. Specifically, the key reason for excessive consumption of coal and auto is that the costs of consuming them are too low, i.e. their current prices do not reflect the negative externalities they generate (in terms of pollution and its future health implications). And the key reasons why alternative energies and subways are not as widely used as they should be is that their prices (costs) are too high and supply is not readily available. Given these reasons, the policy solutions should be quite straightforward. They should include the following:

1. **Raise the resource tax on coal by 5-9 times.** Currently, the resource tax on coal is only equivalent to about 0.7% of output value based on Shangxi data. We think it should be raised to at least 5%, in order to contain demand growth. According to a study by Jiao Jianling, demand elasticity of coal to coal price is 0.96. This conclusion suggests that a 2% annual reduction in coal demand

growth (our new forecast vs. old forecast) requires roughly a 2ppt in the resource tax on coal each year in the coming two years.[29]

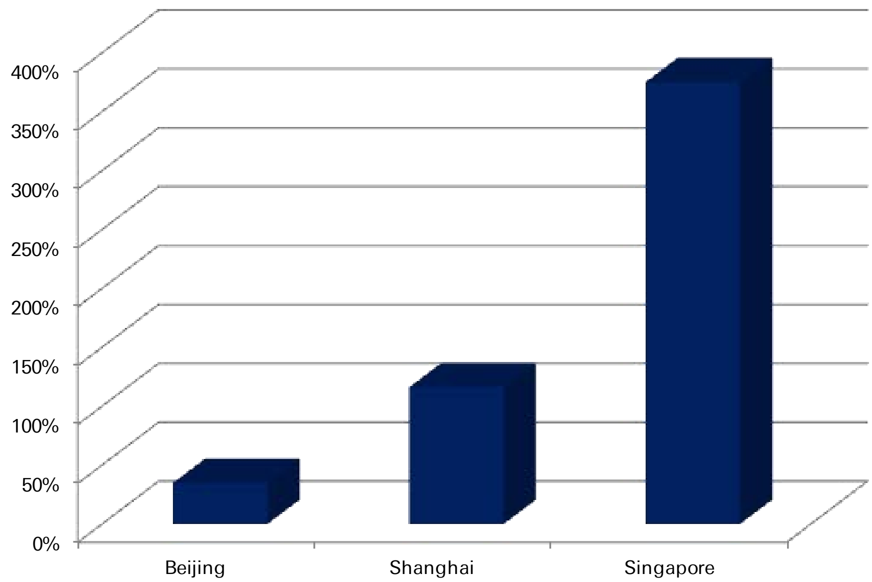
2. **Raise the pollution charges on SO_2 and NO_X by 100-200%.** Currently, from a firm's perspective, paying a fine at the current price is cheaper than installing a treatment facility. For example, a number of provinces charge RMB1.2 per kg on SO2 emission by power plants, while the cost of desulphurization has reached RMB3 per kg. Similarly, the pollution levies on NOx is only RMB1 per kg in most provinces, significantly lower than the cost of treatment. We suggest that these levies be raised by 100-200% so that to incentivize the adoption of treatment facilities. In addition, the pollution charges on smoke emission, sulfuric acid mist, industrial dust and VOC.

3. **Adopting a car plate auction system in major cities.** In Singapore, the additional cost of owning a private car (including the price of car license plate, import duty, registration fees, etc.) is about 400% of the original car price. The Singaporean government has implemented a range of measures to manage car ownership and usage. These include the Certificate of Entitlement (COE), vehicle taxes, registration fees, Vehicle Quota System (VQS), road taxes and Electronic Road Pricing (ERP). The COE scheme (a car licensing plate auction scheme) aims to peg long-term vehicle population growth at 0.5% a year. All motor vehicles imported into Singapore are slapped with a customs duty of 41% ad valorem. All fees and taxes increase the final price of a mid-sized car by nearly 375% from the original import price (exclusive of import duty). In comparison, fees and taxes on car ownership in Beijing are about 35% of the original car prices. This is one of the reasons why car penetration rate in Beijing is now 1.5x of that in Singapore, even though Beijing's per capita income is much lower (Figure 40).

   We suggest that major cities in China adopt a car plate auction system. The benefits include a substantial reduction in the growth of car ownership thus a reduction in air pollution and congestion, and a substantial increase in local government revenue. In Shanghai, the only Chinese city that has adopted such an auction system in the past years, collected RMB7bn in revenue in 2012, equivalent to 65 times the estimated property tax revenue collected by Chongqing province in a year. A large part of the government revenue from the auctions should be allocated to the construction of subways.

[29] Jiao Jianling, "A study on short and long term demand elasticity of coal," Industrial Technical Economics, Vol. 26-4, April 2007.

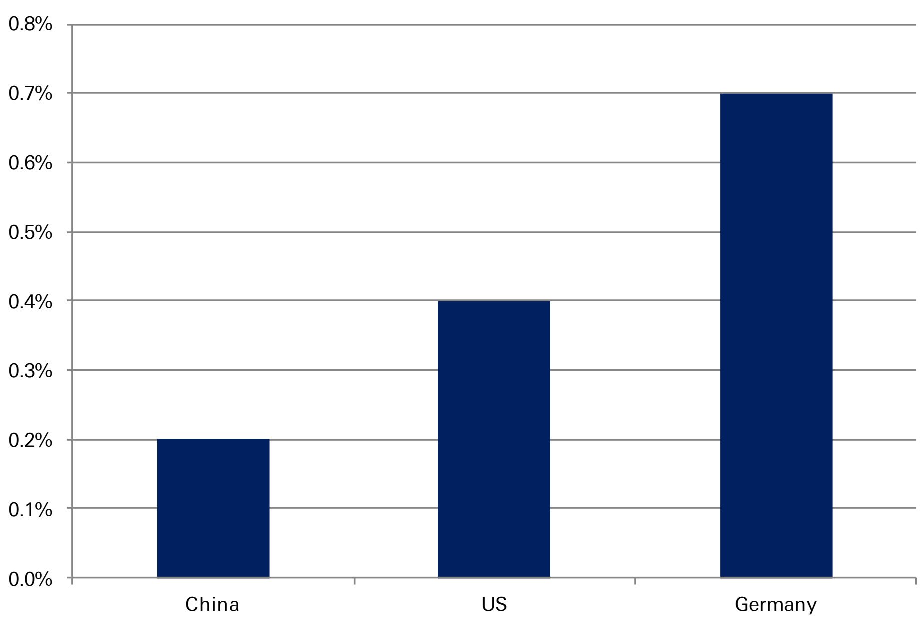
Figure 40: Fees and taxes on cars as % of car price



Source: WIND, China Customs, Xinhua News

4. **Double government subsidies for new energies as percent of total government spending.** Currently the Chinese government allocates 0.2% of its fiscal expenditure to subsidize new energy development, vs. 0.4% and 0.7% in the US and Germany (Figure 41). We suggest that ratio of Chinese government subsidies to be raised by 100% in the coming few years significantly improve the supply of new energies. As we point out later in this report, these additional fiscal costs will be absorbed by the additional revenues from higher resource and environmental taxes/levies and car plant auction incomes.

Figure 41: Government subsidies on new energies as % of government spending, 2011/12



Source: WIND, 21CBN, MoComm, China-Nengyuan.com

Other measures

There are many other measures that the government will need to undertake, in addition to the key policies outlined above. These measures should at least include:

1. Prohibiting the usage of old vehicles that do not meet minimum emission standards.

2. Constructing a large number of central heating systems in Northern Chinese cities.

3. Relocation of newly approved coal plants to less densely populated west/central area.

4. Further emphasis on energy efficiency, by promoting the usage of energy efficient cars and energy savings technologies in industry and construction.

5. Application of stricter dust control policies to construction works.

6. Strict VOC monitoring and control in oil refining, transportation, chemical, construction, printing, automobile production, footwear and furniture sectors.

7. Planting more trees.

Implications for economy and fiscal costs

Many questions have been raised by environmental experts, economists and government officials in our recent discussions with them when we conduct this study. Some technical questions such as the availability of alternative energy sources (such as natural gas) were already discussed in the last chapter. In this chapter, we will address several macro-level issues:

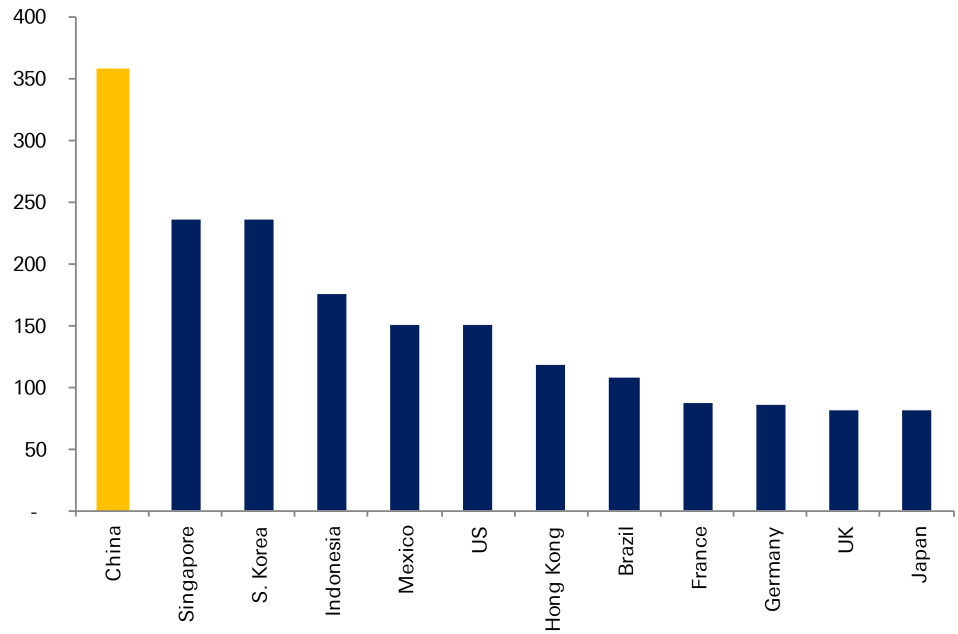
- Will the very aggressive policy package proposed in our study drastically reduce economic growth?
- Will it cost the government a lot of money to implement these policies and can the government afford it?
- Will these policies push up inflation, as many of these would imply higher costs for consumers and firms?

In the following sections, we will answer these questions. Our key conclusions are that the proposed policy package is consistent with a 6.8% annual average GDP growth in the coming 18 years, and the fiscal costs of implementing these costs can be largely financed by the increase in environmental levies and higher resource taxes, and the inflationary pressure is modest (about 0.1ppts per year).

Our proposal is consistent with 6.8% GDP CAGR from 2013-30

Although our policy package envisions a 0.8% annual average reduction in coal consumption from 2013-30, it does not require a reduction in total energy consumption during this period. In fact, our forecast allows a 3.4% annual average increase in total energy consumption, which is based on an energy elasticity of 0.5 to GDP growth and 6.8% annual average real GDP growth. The elasticity of 0.5 is achievable via a structural shift in the economy (towards services) and wider application of energy saving technologies. This point is illustrated in Figure 42, which shows that China's energy intensity remains three times the level in OECD countries. By applying an energy elasticity of 0.5 to the next 18 years, it only requires China's energy intensity to drop by 53%, to a level that is still slightly higher than the current OECD average.

Figure 42: Energy intensity (primary energy consumption, tonnes oil equivalent per mn USD GDP, 2011)

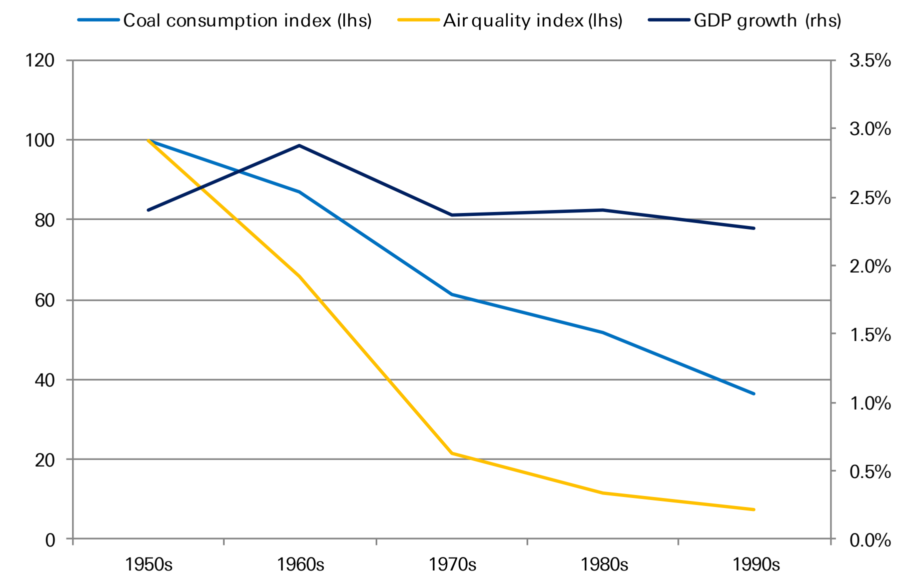


Source: WDI, BP statistical review of world energy 2012, Deutsche Bank

This means that our target for energy consumption is technically feasible and is consistent with an annual average GDP growth rate of about 6.8%. This annual rate of GDP growth is even considered as optimistic by many observers. If one adopts a slower GDP growth rate but the same energy elasticity, it would allow an even faster reduction in total energy growth and earlier achievement of the PM2.5 target.

In addition, one can look at the UK experience as a reference to the growth impact of a major energy mix change. Figure 43 shows that although UK's coal consumption declined drastically during 1950-80s, and as a result air quality improved significantly, its GDP growth remained largely steady during this period. This means that stability of GDP growth is practically achievable during a drastic energy mix change and aggressive air quality control.

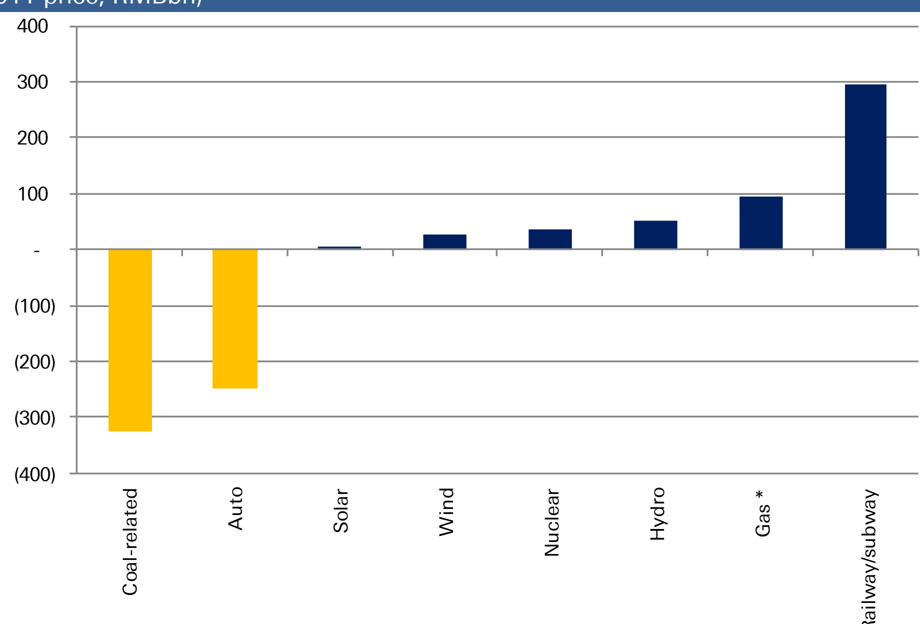
Figure 43: UK: coal consumption, GDP growth and air quality, 1950s-90s



Source: Deutsche Bank, Office of National Statistics UK, Department of Energy and Climate Change UK, AEA Environmental Protection

At the sectoral level, the simple reason why our proposal policy does not necessarily lead to a deceleration in GDP growth is that, while coal and auto consumption growth declines relative to our base case (no reform), new energies, railways, subways and telecommunications sectors expand more quickly than before under our reform scenario. Our calculation shows that, in 2020, the decrease in GDP from the coal and auto sectors due to our proposed policy changes (relative to base case) is largely offset by the increase in the beneficiary sectors such as new energies and public transportation (Figure 44).

Figure 44: Changes in GDP by sector due to tougher environmental policies, 2020 (in 2011 price, RMBbn)



Source: Deutsche Bank, Note: We assume 50% gas is domestically produced.

No increase in the fiscal deficit

A common perception is that implementing an aggressive anti-pollution package (like the one we suggest in this report) would involve significant costs for the government (fiscal cost), companies (higher costs) and consumers (higher inflation). In this section, we attempt to quantify the fiscal costs for the government.

The main fiscal cost facing the government is the required amount of subsidies for developing clean energies. Other policy actions, including those to limit the growth of coal and auto consumption, may in fact be contributing more revenues to the government as they will involve higher environmental levies and resource taxes, as well as fee incomes from car license plate auctions. It is therefore important to estimate the net fiscal implication for the government. Implementing the National V standards for gasoline and car emissions will result in higher fuel costs and car prices, and these costs will be absorbed by the corporates and consumers. We will discuss these non-fiscal costs in the final subsection of this chapter.

China's clean energy subsidies are mainly for wind, solar, and shale gas production, electric cars, as well as for implementing clean air technologies. Presently, wind power producers receive a subsidy of RMB0.21-0.28/kwh, and solar power producers receive about RMB0.5/kwh. The subsidy for shale gas production is about RMB0.4/cm, and that for electric cars is on average about RMB100,000 per unit. If wind, solar, shale gas and electric cars should develop at the pace that we expect, the annual fiscal subsidy required from the government will increase from the current0.2% of total government spending to 0.3% in 2015 and 0.4% in 2017.

This increase in fiscal subsidies can easily be covered by the additional fiscal revenue from the increase in the resource tax rate on coal to 5% from the current 0.7%. If environmental levies on air pollution and fees from car license plate auctions are also taken into account, our preliminary estimates show that these incomes as % of total government spending will rise from 0.3% in 2012 to 0.9% in 2015. The increase in government revenue will significantly exceed the increase subsidies for new energies and electric cars. The extra revenue can be used towards other environment-related spending, such as subway construction, water treatment and tree planting.

In sum, the extra fiscal subsidies needed for new energies and electric cars can be more than absorbed by the increase in the resource tax rates, higher environmental levies/taxes, and car license plate auction income. Therefore, on a net basis, the policy package we proposed would not lead to a higher fiscal deficit.

Impact on CPI is only 0.1% per year

The costs for companies are in the form of higher energy prices (due to, for example; additional costs for installing and running emission control facilities, higher gasoline standards, and higher car prices). Given that the government is committed to liberalizing resource prices, at least part of these cost increases will pass through to consumers via higher prices of power, fuels, and cars.

Our calculation shows that the reforms we envisage may result in a 5% increase in gasoline prices (due to the implementation of the National V standard), a 3% rise in the average price of automobiles (due to the requirement of National V emission standard), as well as 5% rise in power tariffs (due to stricter requirement for desulphurization, denitration and subsidies for renewable, as well as higher resource taxes on coal), and a

30% rise in natural gas prices (as part of the existing reform plan). Some specific details are discussed below.

1. Desulphurization/denitration and power tariffs: According to Xu Fangjie from ChangCe Thinktank, accelerating desulphurization will not push up power tariffs, as China has already implemented a RMB1.5 cents per kwh increase based on the fare for desulphurized electricity. As for denitration price, the estimate from State Electricity Regulatory Commission shows that the price increase will be 1 cent per kwh.

2. Euro V standard for gasoline: According to C1 Energy, 64% of Sinopec's refining and 23% of PetroChina's refining can supply National IV standard gasoline. If Sinopec and PetroChina upgrade all their refining capacities to National IV level, they need to invest between RMB50bn and RMB60bn. Another RMB88.7bn will be needed for Sinopec to further upgrade its refining to National V level and RMB129.6bn for PetroChina. That means a RMB22.2bn and RMB32.4bn investment in four years, accounting for 30% and 24% of Sinopec and PetroChina's profits in 2011. For most cities in China, the usage of Euro V standard gasoline will increase the fuel price by RMB0.34/L.

3. Vehicle emission standard and car prices: According to Limits and Measurement Methods for Emissions of Pollutants From Light-duty Vehicles (China Fifth Stage) (Draft), the production cost of a 2.0L light-duty vehicle will be RMB2,000 higher than that based on National IV standard. We expect that customers will bear 80% of the increase (RMB1,600) and vehicle producers 20% (RMB400).

Based on the above, our CGE model (which reflects the second and third round impact of price changes) shows that the cumulative CPI impact is about 0.3%. If these measures are implemented gradually within three years, the annual average impact is only 0.1ppts on CPI inflation.

Sector implications

The previous chapter presented a set of sector targets and policies that are consistent with the objective of reducing PM2.5 to 30 by 2030. While these proposals are indicative in nature, we do believe that actual policy changes will move in the same direction as suggested. This means a significant reduction in coal consumption growth. On the contrary, gas, nuclear, wind, solar and railway/subway construction will likely see meaningful upward revisions to growth forecasts in the many years to come. The impact on the auto industry appears to be mixed as China's export potential may partly compensate for its domestic sales deceleration.

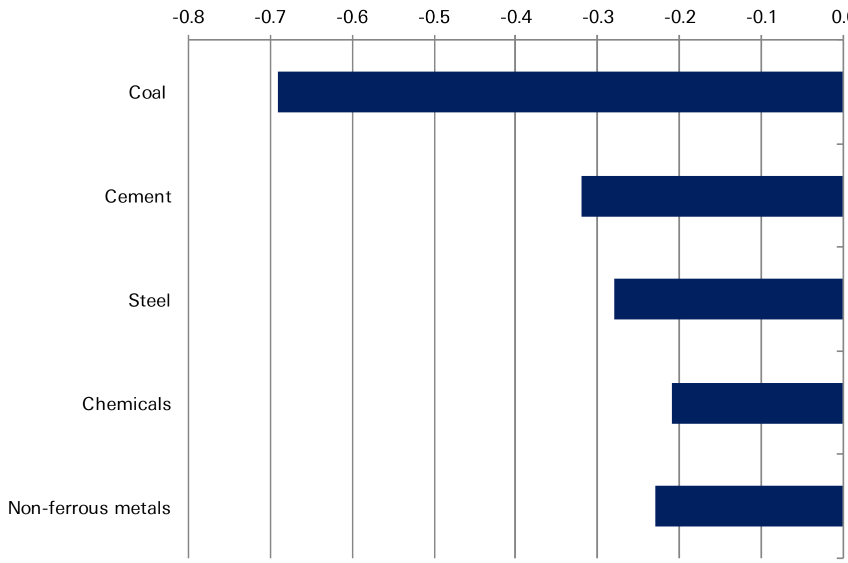
Loser # 1: Coal

Our projection of coal consumption under the proposed policy package is substantially lower than current market consensus. Our new forecast looks for only 2.7% annual average growth of coal consumption from 2013-16, vs. our old forecast and market expectations of about 4% (Figure 48). If the long-term volume growth is reduced by more than half, and the sector's pricing power and profit margin are also lowered due to weaker-than-expected demand, the market reaction could be a de-rating of 20% (e.g. the PE multiple contracts to 7x from 9x), according to cross-country data. We do not think it will happen in the very short term, but do believe it will come sooner than many investors' perception.

Our coal analyst, James Kan, believes that if the coal consumption scenario under the proposed policy package indeed materializes, China will potentially become a net exporter of coal again (currently China net imports about 200mt a year). That will impact the regional coal industry as well because China's net import of thermal coal accounts for one quarter of international seaborne thermal coal market. By 2015, thermal coal price could be lower than the current level and marginal cost producers would be pushed out of the economical supply. Loser # 2: Polluting raw material processors

The forthcoming policy changes to fight pollution will result in higher prices for power, (partly due to higher coal prices reflecting more aggressive resource taxation and environmental levies), coal, natural gas, water, and automobiles. These changes will result in higher costs and lower margins for energy intensive sectors such as processors of steel, cement and non-ferrous metal, as well as chemical materials producers. In addition, higher environmental levies and stricter pollution standards will further reduce the profitability of these sectors. Our updated CGE model simulation shows that these sectors are likely to see margin compression in magnitudes as illustrated in Figure 49, assuming a 5% increase in coal, power and oil prices, a 30% rise in gas price, and a 3% rise in cost of owning cars.

Figure 45: Change in before-tax profit margin of raw material sectors relative to baseline (in ppt)



Source: Deutsche Bank CGE model

At the firm level, higher energy prices (especially power tariffs) will likely squeeze margins for most companies in these sectors at least initially. Tougher environmental standards and levies will severely impact smaller producers, while large producers that are already meeting the standards will be less affected. In the longer term, these policy changes will speed up industrial consolation, and major players may benefit from rising market shares as their smaller competitors exit from the industries.

Winner # 1: Gas

Our PM2.5 reduction model argues that the target for gas consumption growth should be raised to 14% p.a. from the current forecast of 10% p.a. from 2013-20. We have also shown that this is feasible given the significant discovery of non-conventional inventories of shale gas and CBM in China.

If annual gas consumption growth is indeed boosted by 4ppts, the market reaction should be very positive for both the midstream and downstream gas players. However, the distribution of benefits depends on how much of the incremental volume will be supplied through downstream gas utilities. Downstream gas utilities will benefit less if most of the gas consumption increase is for gas-fired power plants, which are likely to source gas directly from the upstream. As for production of gas, the development of shale gas will require massive investments in drilling and exploitation, which will benefit companies that control gas production in China, should also see a rapid rise in conventional, shale gas and CBM production, although its contribution to overall PetroChina revenue will remain below 10% in the coming few years.

Winner # 2: Railways and subways

We argued that in order to meet the PM2.5 reduction target, China will have to slow its car consumption growth and significantly increase its investments in railways and subways. Specifically, we forecast the need to increase the railway length by 60% and the subway length by four fold from 2013-20. These new targets are 15% and 40% higher than current forecasts for railway length and subway length, respectively. The impact of these changes will be highly positive for railway/subway construction, equipment makers, as well as their operators.

These new targets suggest that the annual investment in railways will need to be at Rmb770bn for 2013-20, up from the current forecast of Rmb530bn under the government plan. For subways, the annual investment growth in subways should be increased to 17% from 3% per annum for 2013-2020.

Winner # 3: Wind equipment and ultra voltage transmission

Rising environmental concerns suggest further policy support for wind power. With a 20% CAGR from 2012-20 in our new forecast, wind power will likely become a major substituent for thermal power. Wind power plants, equipment producers and ultra voltage transmission companies will likely benefit.

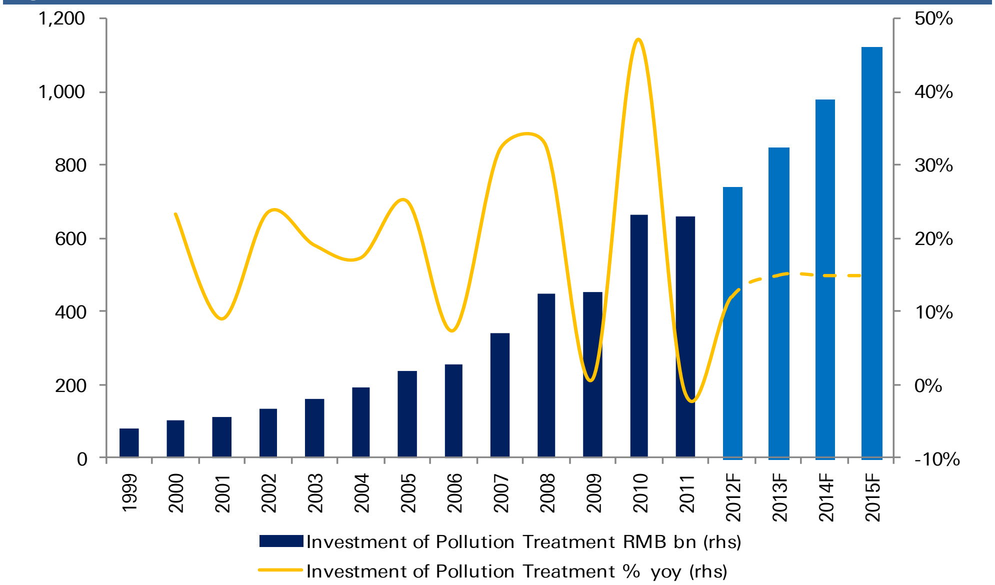
We like major wind equipment companies especially, as the industry is at an inflection point after consolidation in the past two years. A sharp rise in new capacity installation, from 14GW in 2012 to 18GW in 2013 and even more in the coming years, will lead to resumed order growth and a rebound in turbine prices. We believe tier-one players are to solidify their market-leading positions in the new round of industry boom.

Moreover, we believe China should and will likely reallocate power plants to less densely populated area, as most wind/hydro resources are located in remote south west/northwest provinces. More build-up of ultra high voltage transmission lines for supply power to the east is needed.

Winner # 4: Clean tech

Our PM2.5 model shows that China needs to reduce emission per ton of coal consumption by about 70% via the application of clean technologies such as desulphurization and denitration. The MEP recently issued a number of guidelines on tougher emission standards and more aggressive enforcement. Against this backdrop, we believe that investment in pollution treatment will pick up again from 2011's decline and keep double-digit growth for the coming years.

Figure 46: Pollution treatment investment to rise rapidly



Source: Deutsche Bank, CEIC

The beneficiaries of these efforts include:

1. **Monitoring equipment.** China has put in place stricter air quality standards and will extend the monitoring of PM2.5 to 113 model cities on the state environmental protection list and all cities in 2015. In all, China needs to invest at least RMB2bn on equipment and technologies to build a nationwide monitoring network.
2. **Central heating systems.** Wang Anshun, acting mayor of Beijing, said that the city will replace 1,600 coal-burning boilers downtown and the heating systems of 44,000 aging single-story houses with clean energy sources such as central heating systems.
3. **Desulphurization and denitration equipment.** As large part of PM2.5 comes from coal burning and industrial production, the government will require a higher rate of desulphurization, denitration, demercuration and dust control of coal power and industrial plants. Demand for the treatment facilities will rise rapidly.

Mixed outlook: Auto

The auto sector will likely to see some deceleration of domestic sales growth if aggressive policies are enforced to raise the gasoline standards (implying higher fuel prices), car emission standards (implying modestly higher auto prices), and a car license plate auction system is adopted by more cities (implying higher costs of owning a car). However, one should also take into account the fact that China may become a major exporter in the coming 10-20 years due to improvement in technologies and growing export competitiveness. And auto makers that produce electric cars and buses are likely to enjoy strong growth going forward as environmental policies change.

Our PM2.5 reduction model suggests that the total number of passenger cars should be capped at 250mn by 2030. This translates into an annual average car sales growth of about 5% for the coming 18 years. We think the car sales growth can be distributed rather evenly (i.e. no sharp deceleration over time) as over the medium term the rising replacement rate (currently at about 4%, which is likely to rise to 13% by 2030) will help support the car sales growth from 2020-30. Therefore, in the coming few years, the market will likely adjust its expectation gradually towards a 5% sales growth, from the current pace of about 10%.

The main upside risk for the Chinese auto sector is its export potential. With another 10-20 years of development, China will likely see a significant increase in its export/production ratio. Currently, China only exports 3% of the PVs produced locally. By 2030, we believe this export ratio can easily reach 20% (note that major Japanese auto producers export more than 50% of their products today) and Chinese exports will take up 6-7% of global market share. This implies that China will be able to export about 6mn PVs per year in 2030. As a result, China-based production (including for domestic sales and for exports) will grow at about 7% p.a. for the coming 18 years. This outlook remains reasonably positive, compared with 2-3% annual sales growth for major auto makers in the Western countries.

The new environmental policy will likely re-emphasize the usage of buses as a more energy efficient and less polluting mode of transportation. The long-term growth of bus sales will likely exceed that of passenger cars. As for electric cars, the current target of producing 1mn units in 2020 is likely to be too conservative. We see the scope of increasing this target by several folds as infrastructure (such as charging stations) improves.

Appendix A: Lessons from London's "Great Smog"

To envision how the Chinese government might tackle air pollution, it would be useful to review the experience of London, in the aftermath of the 1952 Great Smog.

The Great Smog in 1952

London in 1952 had the same experience as Beijing today. The Great Smog of '52, caused by collected pollutants (sulphur dioxide mainly) and windless conditions, was one of the biggest disasters in the European history. A UK government medical report estimated that 4,000 people had died prematurely and 100,000 more were made ill because of the smog's effects on the human respiratory tract. More recent research suggests that the total number of premature mortality was considerably greater at 12,000[30].

The United Kingdom in 1950s shared many similarities with today's China in terms of per capita GDP level (measured in constant PPP), its economic structure and the dominance of heavy manufacturing in its total output. In particular, coal consumption was as high as 90% of total energy consumption in the UK in the early 1950s, higher than the 70% in China now (Figure 47).

Figure 47: UK in 1950s had similar economic background with China today

Items		UK (1950s)	China (2000s)
GDP per capita (PPP in constant 1990 International Dollar)		6,939 (1950)	6439 (2006)
Industrial structure	Agriculture	~4% (1950)	10% (2012)
	Industry	~51% (1950)	45% (2012)
	Service	~45% (1950)	45% (2012)
Energy structure	Coal	90% (1948)	68% (2011)
Main causes of pollution		Sulphur dioxide	Sulphur dioxide, nitrogen oxides

Source: Deutsche Bank, CEIC, Department of Energy & Climate Change UK, Angus Maddison, World Economy, 1–2030 AD; Note: the GDP per capita numbers for UK (1950) is from Angus Maddsion's World Economy, 1–2030, the China 2006 number is estimated by DB based on Maddsion's work and WDI data.

UK government and legal actions

The Great Smog didn't draw much attention from authorities in the first several days. It was not until the death figure was reported and public discontent soared when the government started to seriously consider legislation. In response to the social and political pressure from the public, the UK legislatures and government introduced a series of new laws and measures in the subsequent years (Figure 48). In particular,

1. **The government offered financial incentives to householders to replace traditional coal fires with alternatives fuelled by gas, oil, smokeless coal or electricity;**

2. **London banned the burning of domestic fuel;**

[30] Michelle L. Bell, Devra L. Davis, Tony Fletche, A Retrospective Assessment of Mortality from the London Smog Episode of 1952: The Role of Influenza and Pollution". Environ Health Perspective 112 (1): 6–8.

3. **Companies burning coal were required to use tall chimneys; and**

4. **The authority also relocated the power stations to more rural areas and reduced heavy industry.**

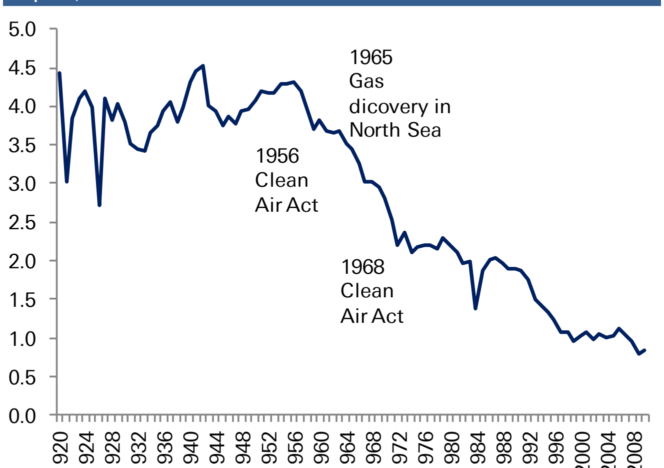
Figure 48: UK legislation efforts under public pressure

1956 - Clean Air Act	Introduced Smoke control Areas, controlled chimney heights. Prohibited emission of dark smoke from chimneys, with some exceptions.
1968 - Clean Air Act	Extended the smoke control provisions of the 1956 Act and added further prohibitions on dark smoke emission.
1974 - Control of Pollution Act	Allowed for the regulation of the composition of motor fuels. In addition the Act limited the amount of sulfur in fuel oil.
1981 - The Motor Fuel (Lead content of Petrol) Regulation	Limited the maximum amount of lead in petrol to 0.4 grams per liter.
1989 - The Air Quality Standards Regulations	Limit and guide values for SO_2 and suspended particulates, lead in air and nitrogen dioxide set by European Community was brought into UK.
1991 - The Road Vehicles Regulations	Set standards for in service emissions of carbon monoxide and hydrocarbons to be included in the Ministry of Transport test for petrol cars and light goods vehicles.

Source: Deutsche Bank

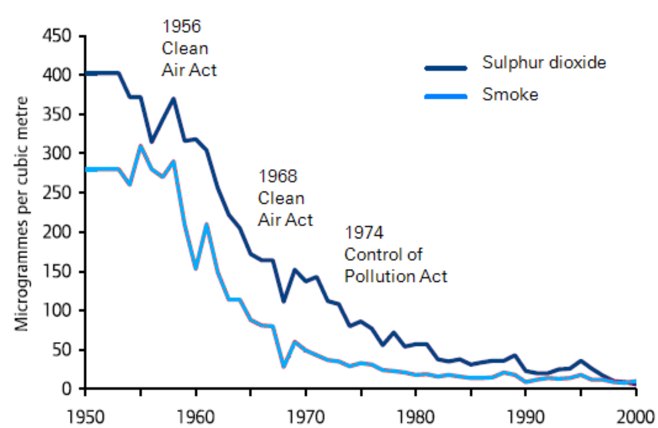
As a result of these strong policy interventions, the percentage of coal consumption in total energy consumption declined by nearly 40ppts in the 15 years after the Great Smog (Figure 49, Figure 51). Sulphur dioxide and nitrogen oxides emissions were significantly reduced throughout most of the country, and the number of "Smog days" per annum in London declined from over 90 days prior to 1950 to less than five days in 1980s (Figure 50).

Figure 49: Coal consumption per capita UK (tonnes per capita)



Source: Deutsche Bank, Office of National Statistics UK, Department of Energy and Climate Change UK

Figure 50: Annual average smoke and sulphur dioxide concentrations in London 1950 to 2000



Source: Deutsche Bank, AEA Environmental Protection

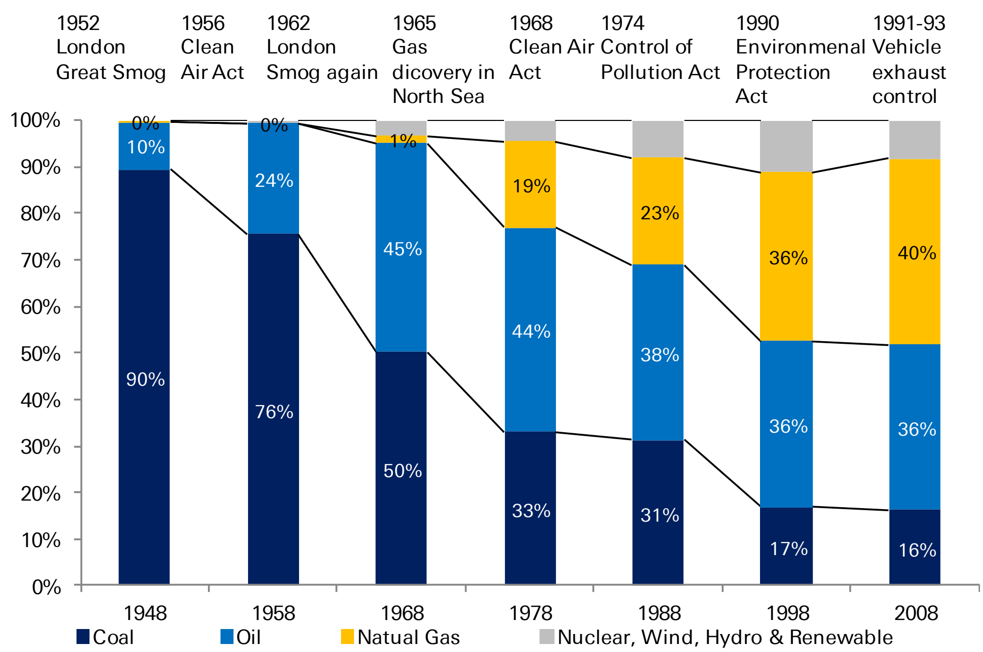
Among the many policies, we believe the following two sets had made the most visible impact:

1. **Emission control:** The Clean Air Act in 1956 instituted "smoke control area" in cities where only smokeless fuels could be burnt. It also promoted clean coal heating in households and relocated power plants away from downtown. The 1968 Clean Air Act reinforced the provision for abating sulphur dioxide emission, by introducing tall chimneys for coal burning factories to disperse

pollution. The Control of Pollution Act in 1974 finalized the cap of sulphur content in fuels. As vehicle exhaust pollution became serious after 80s, the catalytic converters, devices designed to reduce nitrogen oxides emissions, have been required in all new cars in UK by The Road Vehicles Regulations since the early 90s.

2. **Energy diversification and upgrade:** Coal accounted for 76% of primary energy consumption in the UK in 1958. The British government has directed a successful structural shift by encouraging the switch from coal to oil, gas and later on renewable energy. Thanks to joint efforts of government R&D expense and private sector exploitation, sufficient gas reserve was discovered in North Sea in mid-60s, which was later commercialized in 70s. The increased popularity of natural gas (40+% of total consumption today) has squeezed the coal consumption to less than 20% of total energy usage;

Figure 51: Roadmap of UK environment protection and energy composition change



Source: Deutsche Bank, Department of Environment and Climate Change, UK

The UK experience suggests that during the 1950s and 60s, the economic structure, per capita energy consumption, and the composition of energy consumption all changed drastically. In particular, between 1950 and 1970, the UK witnessed the following changes:

1. Industry as a percentage of GDP fell by 9ppts to 42%, while the service industry as % of GDP rose by 10ppts to 55% during 1950-70.

2. Energy consumption per GDP unit (constant price) declined by 19% from 1948 to 1968.

3. Per capita coal consumption declined by a cumulative 31% during 1950-70. On an annual basis, coal consumption declined by 1.5% per year.

4. Coal consumption as % of total energy consumption declined from 90% of 1948 to 50% by 1968.

These figures show that massive structural changes in the UK economy during the two decades were fundamentally responsible for the improvement of the air quality. The logic is simple: only when the industry sector shrinks relative to the size of the economy, energy consumption would decline; only if cleaner energy consumption as % of total energy consumption rises sharply, can the sulfur dioxide emission be controlled. These mean that, in China, the tasks for improving air quality are not merely the job of the MEP, but much more the responsibility of the top policy makers who can shape the direction of the overall economic and energy structure.

Appendix 1

Important Disclosures

Additional information available upon request

For disclosures pertaining to recommendations or estimates made on securities other than the primary subject of this research, please see the most recently published company report or visit our global disclosure look-up page on our website at http://gm.db.com/ger/disclosure/DisclosureDirectory.eqsr

Analyst Certification

The views expressed in this report accurately reflect the personal views of the undersigned lead analyst(s). In addition, the undersigned lead analyst(s) has not and will not receive any compensation for providing a specific recommendation or view in this report. Jun Ma/Michael Tong/Audrey Shi

Regulatory Disclosures

1. Important Additional Conflict Disclosures

Aside from within this report, important conflict disclosures can also be found at https://gm.db.com/equities under the "Disclosures Lookup" and "Legal" tabs. Investors are strongly encouraged to review this information before investing.

2. Short-Term Trade Ideas

Deutsche Bank equity research analysts sometimes have shorter-term trade ideas (known as SOLAR ideas) that are consistent or inconsistent with Deutsche Bank's existing longer term ratings. These trade ideas can be found at the SOLAR link at http://gm.db.com.

3. Country-Specific Disclosures

Australia and New Zealand: This research, and any access to it, is intended only for "wholesale clients" within the meaning of the Australian Corporations Act and New Zealand Financial Advisors Act respectively.
Brazil: The views expressed above accurately reflect personal views of the authors about the subject company(ies) and its(their) securities, including in relation to Deutsche Bank. The compensation of the equity research analyst(s) is indirectly affected by revenues deriving from the business and financial transactions of Deutsche Bank. In cases where at least one Brazil based analyst (identified by a phone number starting with +55 country code) has taken part in the preparation of this research report, the Brazil based analyst whose name appears first assumes primary responsibility for its content from a Brazilian regulatory perspective and for its compliance with CVM Instruction # 483.
EU countries: Disclosures relating to our obligations under MiFiD can be found at http://www.globalmarkets.db.com/riskdisclosures.
Japan: Disclosures under the Financial Instruments and Exchange Law: Company name - Deutsche Securities Inc. Registration number - Registered as a financial instruments dealer by the Head of the Kanto Local Finance Bureau (Kinsho) No. 117. Member of associations: JSDA, Type II Financial Instruments Firms Association, The Financial Futures Association of Japan, Japan Investment Advisers Association. This report is not meant to solicit the purchase of specific financial instruments or related services. We may charge commissions and fees for certain categories of investment advice, products and services. Recommended investment strategies, products and services carry the risk of losses to principal and other losses as a result of changes in market and/or economic trends, and/or fluctuations in market value. Before deciding on the purchase of financial products and/or services, customers should carefully read the relevant disclosures, prospectuses and other documentation. "Moody's", "Standard & Poor's", and "Fitch" mentioned in this report are not registered credit rating agencies in Japan unless "Japan" or "Nippon" is specifically designated in the name of the entity.
Malaysia: Deutsche Bank AG and/or its affiliate(s) may maintain positions in the securities referred to herein and may from time to time offer those securities for purchase or may have an interest to purchase such securities. Deutsche Bank may engage in transactions in a manner inconsistent with the views discussed herein.
Russia: This information, interpretation and opinions submitted herein are not in the context of, and do not constitute, any appraisal or evaluation activity requiring a license in the Russian Federation.

Risks to Fixed Income Positions

Macroeconomic fluctuations often account for most of the risks associated with exposures to instruments that promise to pay fixed or variable interest rates. For an investor that is long fixed rate instruments (thus receiving these cash flows), increases in interest rates naturally lift the discount factors applied to the expected cash flows and thus cause a loss. The longer the maturity of a certain cash flow and the higher the move in the discount factor, the higher will be the loss. Upside surprises in inflation, fiscal funding needs, and FX depreciation rates are among the most common adverse macroeconomic shocks to receivers. But counterparty exposure, issuer creditworthiness, client segmentation, regulation (including changes in assets holding limits for different types of investors), changes in tax policies, currency convertibility (which may constrain currency conversion, repatriation of profits and/or the liquidation of positions), and settlement issues related to local clearing houses are also important risk factors to be considered. The sensitivity of fixed income instruments to macroeconomic shocks may be mitigated by indexing the contracted cash flows to inflation, to FX depreciation, or to specified interest rates - these are common in emerging markets. It is important to note that the index fixings may -- by construction -- lag or mis-measure the actual move in the underlying variables they are intended to track. The choice of the proper fixing (or metric) is particularly important in swaps markets, where floating coupon rates (i.e., coupons indexed to a typically short-dated interest rate reference index) are exchanged for fixed coupons. It is also important to acknowledge that funding in a currency that differs from the currency in which the coupons to be received are denominated carries FX risk. Naturally, options on swaps (swaptions) also bear the risks typical to options in addition to the risks related to rates movements.

David Folkerts-Landau
Global Head of Research

Marcel Cassard
Global Head
CB&S Research

Ralf Hoffmann & Bernhard Speyer
Co-Heads
DB Research

Guy Ashton
Chief Operating Officer
Research

Richard Smith
Associate Director
Equity Research

Asia-Pacific
Fergus Lynch
Regional Head

Germany
Andreas Neubauer
Regional Head

North America
Steve Pollard
Regional Head

International Locations

Deutsche Bank AG
Deutsche Bank Place
Level 16
Corner of Hunter & Phillip Streets
Sydney, NSW 2000
Australia
Tel: (61) 2 8258 1234

Deutsche Bank AG
Große Gallusstraße 10-14
60272 Frankfurt am Main
Germany
Tel: (49) 69 910 00

Deutsche Bank AG
Filiale Hongkong
International Commerce Centre,
1 Austin Road West,Kowloon,
Hong Kong
Tel: (852) 2203 8888

Deutsche Securities Inc.
2-11-1 Nagatacho
Sanno Park Tower
Chiyoda-ku, Tokyo 100-6171
Japan
Tel: (81) 3 5156 6770

Deutsche Bank AG London
1 Great Winchester Street
London EC2N 2EQ
United Kingdom
Tel: (44) 20 7545 8000

Deutsche Bank Securities Inc.
60 Wall Street
New York, NY 10005
United States of America
Tel: (1) 212 250 2500

Global Disclaimer