Chinese Coal-based Thermal Power Sector

Compliance of Environmental Standards

Rock Environment and Energy Institute

Research Director: Lin Jiaqiao
Authors: Lin Jiaqiao, Zhao Ang
Research Team: Elisabeth Freese, Wang Yurui
Design: Wang Hui
Date: March 2017

Rock Environment and Energy Institute
Website: www.reei.org.cn
Email: info@reei.org.cn
Telephone: +86(10)61438032
Address: Houshayu,Shunyi,Beijing,101318,P.R.China

Commissioned by CSE, REEI draft the report to make contribution to the report of Emission Norms for Coal-Based Power.

Citation: J. Lin, *et al*. 2017. Chinese Coal-based Thermal Power Sector: Compliance of Environmental Standards. Rock Environment and Energy Institute, Beijing

Cover picture from Visual China Group

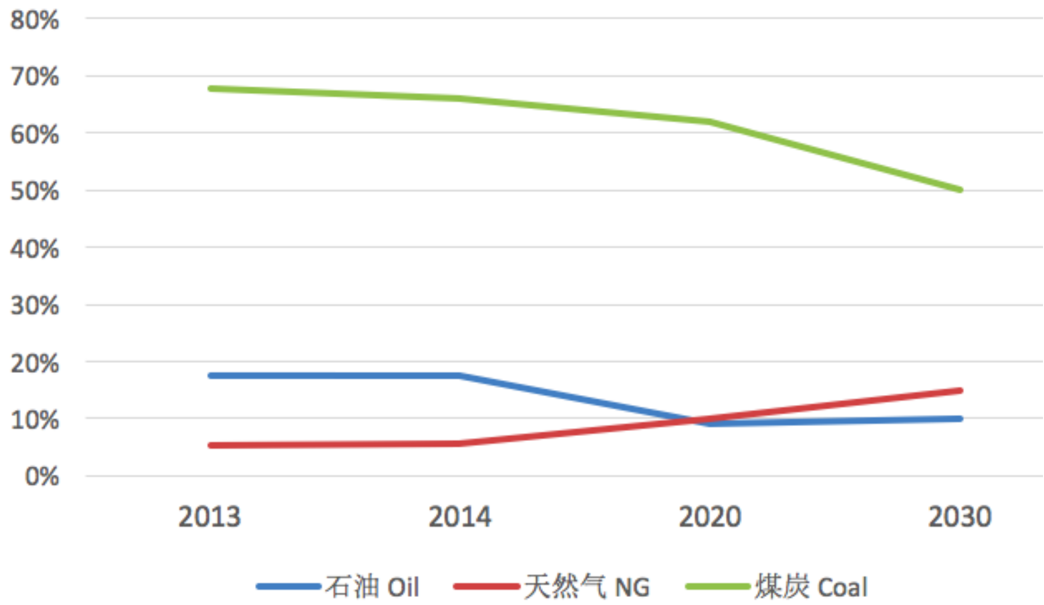
Contents

1. Background on Coal Consumption in China

Since China's reform and opening in the late 1970s, coal consumption has increased due the need to power rapid economic development. In recent years, the energy consumption growth rate has slowed down, and it is expected that in the *'13th Five-Year-Plan on Energy Development'* (2016-2020), the annual average growth rate will be around 2.5%, a 1.1% reduction compared to the 12th FYP[1].

Coal is still the single largest source in China's energy consumption mix, the percentage of coal consumption in 1995 was as high as 70% of total energy consumption, declined to around 65% in 2015, and is estimated to be reduced to 60% in 2020 and 50% in 2030 (**Figure 1**).

Figure 1: Percentage of Fossil Fuels in China's Total Energy Consumption



Data Source: BP Statistical Review of World Energy 2015; Energy Development Strategy Action Plan 2014-2020; China's Future Energy Development Strategy Analysis.

As for the absolute numbers, coal consumption in China just started to decline starting in 2014. In China's *'13th FYP for Coal Industry'*, total coal consumption by 2020 is to be controlled under 4.1 billion tons[2], but by 2015 the national coal consumption was already 3.96 billion tons, which leaves the remaining years more challenging to reach the 2020 target.

The Chinese coal-based thermal power sector (hereafter 'the Chinese Sector') has been the sector that consumes the largest amount of coal in China. According to the latest figures, in 2015 the total coal consumption from the Chinese Sector amounts to around 1.96 billion tons[3] and accounts for 49.5% of total Chinese coal consumption. According to China Electricity Council (CEC), the total

[1] Energy development in the 13th Five-Year Plan issued to adhere to six 'pay more attention to' policy orientation. Link: http://finance.china.com.cn/news/20170105/4056538.shtml (in Chinese)

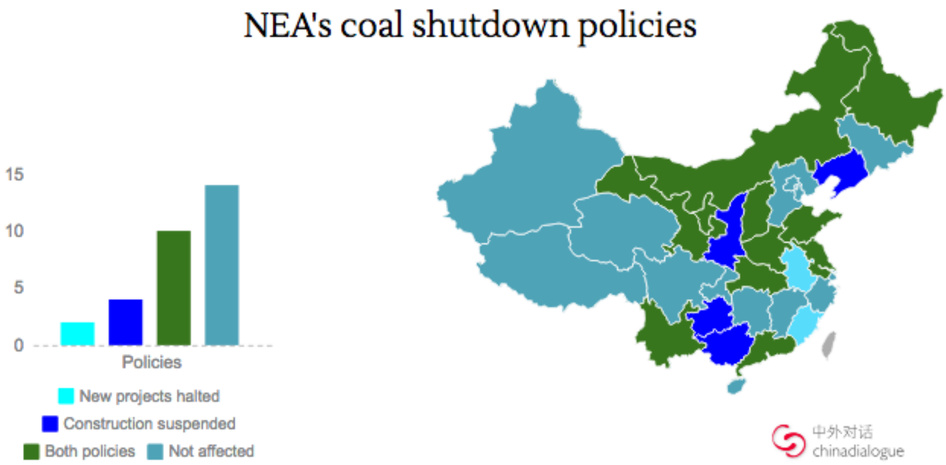
[2] The 13th Five-Year-Plan for the Development of Coal Industry, p15. National Energy Administration. Link: http://www.sdpc.gov.cn/gzdt/201612/W020161230415967105993.pdf (in Chinese)

[3] Calculated based on the figure in '2015 coal consumption in the power industry reached over 1.4 billion tons coal equivalent. Link: http://www.china5e.com/news/news-169411-1.html (in Chinese), Note: 1 ton of raw coal equals to 0.7143 tons coal equivalent (tce)

installed capacity of coal-fired power plants (CFPPs) reached circa 943 GW in 2016, a 5.3% increase compared to 2015 [4].

The large amount of harmful substances emitted from coal combustion have resulted in the deterioration of ambient air quality and large-scale acid degradation, causing serious pollution to the environment and negative impacts to human health. The Ministry of Environmental Protection (MEP), National Development and Reform Commission (NDRC) and National Energy Administration (NEA) have released several regulations to enforce the emissions standards, limit the construction of coal-fired power plants, promote ultra-low emission CFPPs, and facilitate more renewables to the power grid and so on. For example, in March of 2016, the NDRC together with NEA released the *'Notice on Improving the Orderly Development of Coal-fired Power Plants'*[5] to limit the pace of the Chinese Sector's development by halting new projects and suspending construction in certain regions (**Figure 2**). The Notice requires that the obsolete generation units of 20-25 years old should retire in priority in 2016-2020 if these units are below 300 MW capacity. In September 2016, 15 proposed CFPPs, which accounted for 12.4 GW of capacity, were suspended by NEA due to the overcapacity of coal power fleet and low growth of national electricity consumption, the total number of CFPPs affected by the new policy was estimated to be around 110 GW[6].

Figure 2: Illustration on NEA' s New Coal-fired Power Plants Policy



Source: China pulls emergency stop on coal power construction. China Dialogue, April 06th 2016[7]

Current regulations on coal consumption by the Chinese Sector focus more on emission standards enforcement. The environmental departments are playing a supervisory role, but enforcement has been poor due to the weak role of environmental departments of provincial and municipal governments as the leaders of local environmental governments are appointed by the governors or

[4] National Power Industry Statistical Brief 2016. China Electricity Council (CEC) 2017. Link: http://www.cec.org.cn/guihuayutongji/tongjxinxi/niandushuju/2017-01-20/164007.html (in Chinese)

[5] Notice on Improving the Orderly Development of Coal-fired Power Plants, NDRC and NEA 2016. Link: http://www.nea.gov.cn/2016-04/25/c_135309112.htm (in Chinese)

[6] Coal emergency brake: Energy Bureau stopped substandard coal power project installed quite half of the Three Gorges. The Paper, September24th2016. Link: http://www.thepaper.cn/newsDetail_forward_1533668 (in Chinese)

[7] China pulls emergency stop on coal power construction, China Dialogue. Link: https://www.chinadialogue.net/article/show/single/en/8794-China-pulls-emergency-stop-on-coal-power-construction

mayors rather than by MEP. The upgraded high standards also make enforcement demanding technically. Even if the air pollutants emission standards are all met, the lack of a total consumption cap on coal could still lead to the deterioration of the environment; therefore, it is necessary to position environmental health in the center. More stringent emissions standards and stricter cap on coal consumption should aim for better environmental quality that can ensure both healthy environment and benefits to public health.

Fortunately, there has been considerable progress in total pollutants control in recent years. Due to the occurrence of severe air pollution events and the induced extensive discussion, a more stringent revision of the *'Law on Air Pollution Prevention and Control'* was passed in 2015, stipulating total quantity control of air pollutants by law. However, the pollution control section in coal combustion does not mention the consumption cap on coal, meaning the pollutants from coal can still rise. But based on current trends, coal consumption has been declining and future trends of pollutants from the Chinese Sector can be further lowered considering the increasingly stringent emissions standards.

This report will review the regulatory policies and environmental standards of the Chinese coal-based thermal power sector, the pollution control and monitoring practices, and the future policy trends regarding air pollution from the Chinese Sector.

2. Overview of the Chinese Coal-based Thermal Power Sector

The total number of existing CFPPs are around 2,500, and are estimated to reach 2,900 if all new capacity is online[8], but due to the new order from the NEA and the CFPP installed capacity cap set for 2020, the total number of CFPPs to be operated by 2020 in China should be within the range of 2,500-2,700. The Chinese Sector is faced with a severe over capacity problem; dwindling demand for electricity due to weaker economic growth and the slashing of energy intensive industries has caused widespread underutilization of existing coal-fired power generation capacities. The lowest annual operation hours since 1978 were seen in 2016, at only slightly above 4,100 hours (**Figure 3**). However, CFPPs are still being built because many projects were approved when the economy was still expected to grow as before. Under the *'13th FYP on Energy Development'*, the approval of any new coal-fired power projects is frozen for two years, total coal power capacity should remain below 1,100 GW by 2020[9], which means that during 2016-2020 the net average annual growth of coal power capacity is around 40 GW (**Table 1**). The decommission of obsolete CFPPs in 2016 was close to 5 GW, and it is estimated that the number will amount to 4 GW for 2017, according to the *'Guiding Opinions on the Energy-related Work in 2017'* from NEA at the beginning of 2017 [10].

To control the increasing number of CFPPs, in January 2017 NEA issued a new order to suspend a number of CFPPs, accounting for 22.2 GW of capacity, while 20 GW of CFPPs will be shut down

8 China's coal expansion will face air pollution and water shortages. Greenpeace. Link: http://www.greenpeace.org/china/zh/news/releases/climate-energy/2013/12/coal-power-issue/ (in Chinese)

9 China raises its low carbon ambitions in new 2020 targets, China Dialogue. Link: https://chinadialogue.org.cn/article/show/single/en/9532-China-raises-its-low-carbon-ambitions-in-new-2-2-targets

10 Guiding Opinions on the Energy-related Work in 2017. NEA 2017. Link: http://zfxxgk.nea.gov.cn/auto82/201702/t20170217_2602.htm (in Chinese)

during 2016-2020[11]. Meantime, it is estimated that 420 GW of CFPPs will be retrofitted to ultra-low emissions, and 340 GW will have energy efficiency upgrades by 2020 [12]. Based on the limit on total capacity of CFPPs and the declining utilization hours (**Figure 3**), it could be estimated that after 2020 the coal consumption in the Chinese Sector should be reduced, and the long-term declining trend should continue since the cap on carbon emissions around 2030 had been announce by the Chinese government, which will restrict the room of coal consumption increase by the CFPPs. According the International Energy Agency (IEA) projection under the 2°C Scenario (2DS) and 4°C Scenario (4DS), the projection for the Chinese CFPPs would be lower than the official target of 1,100 GW by 2020, and the projected capacity in 2050 are 734 GW under the 4DS and 530 GW under the 2DS[13]. In comparison, the research done by the Energy Research Institute (ERI) shows that under the high renewable energy penetration scenario[14], the projected capacity in 2020 is similar to the official target, and the 2030 and 2050 figures are 1,052 GW and 887 GW respectively, which should be closer to the future trend of development of CFPPs in China.

Table 1: Historical and Projected Capacity Growth of the Chinese Sector

	Year	2005	2010	2015	2020	2030	2050
Capacity (GW)	Official figures	373	660	895	1,100		
	IEA Scenarios				947 (4DS) 882 (2DS)	N.A.	734 (4DS) 530 (2DS)
	ERI High RE Penetration Scenario				1,083	1,052	887

Source: Author's compilation, based on data from CEC, IEA, and ERI report
Note: 2DS: IEA 2°C Scenario; 4DS: IEA 4°C Scenario

As the main contributor to energy-related greenhouse gas (GHG) emissions, CO_2 emissions from coal consumption reached around 7 billion tons in 2014, accounting for about 70% of China's carbon emissions, and 55%-60% of China's greenhouse gas emissions[15]. In November 2016, the State Council issued the *'13th FYP on Control of Greenhouse Gas Emissions Program*', and for the first time clearly put forward that large-scale power corporations should limit their unit carbon emission of power supply below 550 gCO_2/kWh by the end of 2020[16]. According to a recent study in calculating the CO_2 emissions of CFPP, the current emission rates range from 662-954 gCO_2/kWh, depending on the installed capacity and technology employed[17].

[11] NEA suspends CFPPs in 11 provinces. Link: http://www.guancha.cn/Project/2017_01_17_389838.shtml (in Chinese)

[12] Energy development in the 13th Five-Year Plan issued to adhere to six 'pay more attention to' policy orientation. Link: http://finance.china.com.cn/news/20170105/4056538.shtml (in Chinese)

[13] Emissions Reduction through Upgrade of Coal-Fired Power Plants Learning from Chinese Experience, IEA 2014. Link: https://www.iea.org/publications/freepublications/publication/PartnerCountrySeriesEmissionsReductionthroughUpgradeofCoalFiredPowerPlants.pdf

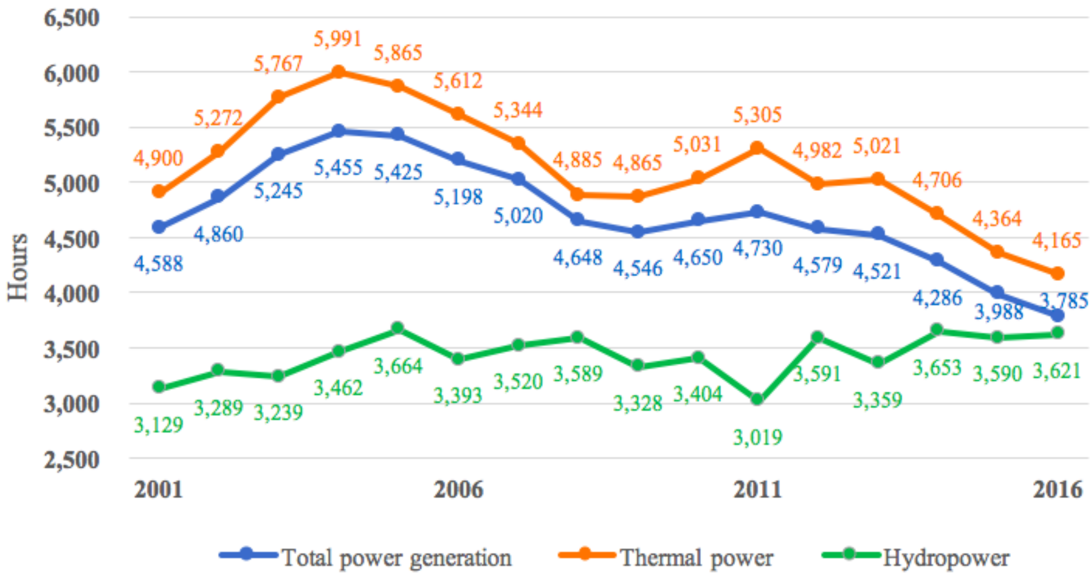
[14] China 2050 High Renewable Energy Penetration Scenario and Roadmap Study, Energy Research Institute (NDRC), 2015. Link: http://www.efchina.org/Attachments/Report/report-20150420/China-2050-High-Renewable-Energy-Penetration-Scenario-and-Roadmap-Study-Executive-Summary.pdf

[15] Climate change and total coal consumption control, NRDC. Link: http://www.nrdc.cn/coalcap/console/Public/Uploads/2015/06/10/Climate%20Report.pdf (in Chinese)

[16] 13th FYP on Control of Greenhouse Gas Emissions Programme. State Council. Link: http://www.gov.cn/zhengce/content/2016-11/04/content_5128619.htm (in Chinese)

[17] Li Jin, Yu Haiqin, Chen Rui. Analysis and application of calculating method for CO_2 emission intensity per unit of electricity generation in coal-fired power plants. 2015. Chinese Journal of Environmental Engineering. Vol.9, No.7 (in Chinese)

Figure 3: Utilization Hours of China's Thermal Power Plant and Hydro Power Plant



Note: Power generation equipment utilization hours are 6000 kilowatts and above power plants;
Data source: China Electricity Council (CEC) and National Power Industry Statistical Brief 2016

By 2015 the number of CFPP units with 1,000 MW capacity or more was over 80, and capacity of between 600 MW and 1,000 MW accounted for over 40% of the total capacity of fleet (895 GW)[18]. Regarding the distribution of installed capacity in the Chinese Sector, **Table 2** shows that the total number of installed coal-fired power generation units (100MW~) was approximately 2,500 in 2014, with an average unit capacity of around 450 MW.

Table 2: Installed Capacity Distribution of Chinese CFPPs with Utilization Hours in 2014

Installed Capacity (MW)	Installed Units	Average Capacity (MW/Unit)	Utilization Hours(h)
100-199	436	135	4,961
200-299	368	207	4,284
300-399	748	333	4,806
400-599	8	504	5,296
600-799	866	643	5,020
800-1,000	64	902	4,865
In sum	**2,490**		

Adapted from China Electricity Statistics Yearbook 2015;
Note: Only CFPPs with capacity more than 100 MW are included in the statistics, since most generation units with installed capacities below 50 MW were closed before 2003, units under 100 MW had been required to shut down during the 11th FYP (2006-2010). The current minimum requirement on newly added units is 300 MW.

[18] CEC launches the Annual Report on China Electricity Development 2016. Link: http://www.cec.org.cn/guihuayutongji/gongzuodongtai/2016-08-24/157409.html (in Chinese)

A report by IEA shows the information related to unit age, technology and capacity of CFPPs in China and other coal power countries[19]. The data for China is for more than 75% of plants based on the information collected by 2010. **Table 3** displays the unit age and corresponding capacity.

Table 3: Unit Age and Corresponding Capacity of Chinese CFPPs

Total Capacity			669 GW
Share of plants that are…	…younger than …years	20	90%
		10	69%
	…larger than 300 MW		75%
	Super- or ultra-supercritical		25%
	..super or ultra-supercritical and younger than … years	20	27%
		10	34%
Case		1	90% (600 GW)
		2	72% (481 GW)
		3	58% (390 GW)

Adapted from 'CCS Retrofit: Analysis of the Global Installed Coal-Fired Power Plant Fleet', IEA 2010.
Note:
Case 1: power plants younger than 30 years and above 100 MW capacity;
Case 2: power plants younger than 20 years and above 300 MW capacity;
Case 3: power plants younger than 10 years and above 300 MW capacity;

Since 2010, Chinese government has tightened the environmental regulation on CFPPs and has decommissioned small scale CFPPs. The new built CFPPs are usually larger than 300 MW. This means large CFPPs have dominated the coal power fleet in China.

The electricity generation from the Sector amounted to 3.9 billion MWh in 2015, a 3.2% reduction compared to 2014, contributing to around 70% of total electricity generation in China[20]. The net coal consumption rate for CFPPs has decreased from circa 374 gce/kWh in 2000 to 318 gce/kWh in 2015 [21], and according to the *'Electric Power Development 13th FYP (2016-2020)'*, the 2020 target for new CFPPs is set at 300 gce/kWh, and for existing CFPPs less than 310 gce/kWh.

[19] Finkenrath, M., *et al*. CCS Retrofit: Analysis of the Global Installed Coal-Fired Power Plant Fleet. Information Paper. IEA. 2012. Link: https://www.iea.org/publications/freepublications/publication/CCS_Retrofit.pdf

[20] CEC launches the Annual Report on China Electricity Development 2016. Link: http://www.cec.org.cn/guihuayutongji/gongzuodongtai/2016-08-24/157409.html (in Chinese)

[21] Electric Power Development 13th FYP (2016-2020). Link: http://www.sdpc.gov.cn/zcfb/zcfbghwb/201612/P020161222570036010274.pdf (in Chinese)

Table 4: Fuel Quality of the Chinese Coal-fired Power Plants

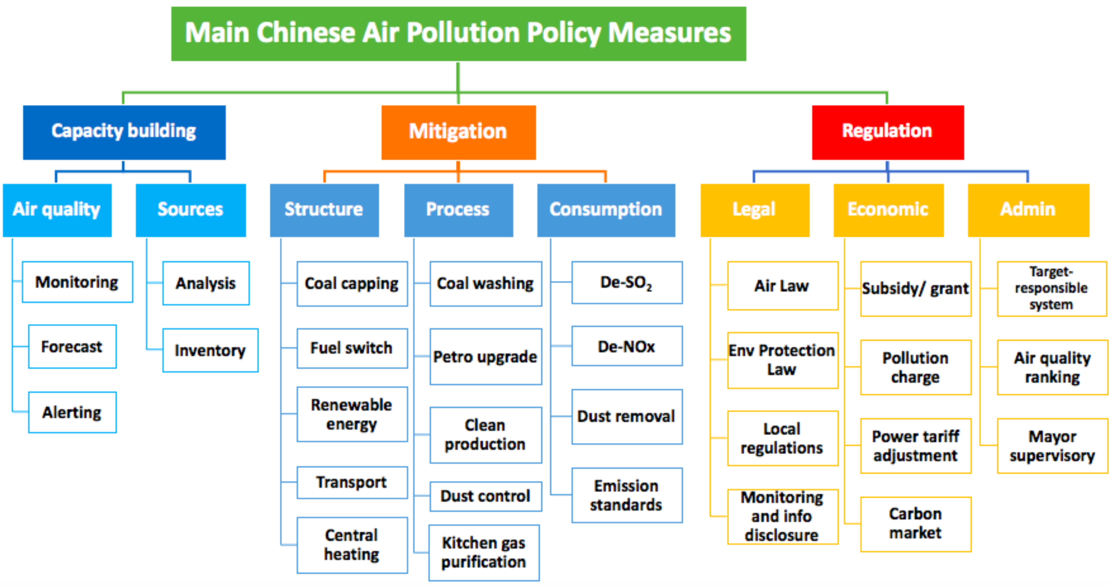
Items	1990	1995	2000	2005	2006	2007	2008	2009	2010
Heating value (kJ/ g of coal)	20.1	20.2	21.0	19.0	19.3	20.0	19.3	18.9	18.8
Net Coal Consumption rate (gce/kWh)	406.7	389.0	374.3	356.4	351.8	343.5	335.3	330.5	327.1
Sulfur content	1.07	1.12	1.10	1.04	1.03	1.00	0.97	0.95	0.95

Adapted from: High-resolution inventory of technologies, activities, and emissions of coal-fired power plants in China from 1990 to 2010. Link: www.atmos-chem-phys.net/15/13299/2015/

3. Environmental Standards in the Chinese Sector

To reduce air pollution, the Chinese government has many policy instruments to achieve its intended targets for different stage of development (**Figure 4**), and the detailed evolution of China's air pollutants mitigation policies can be seen in **Appendix 1**. The Environmental Protection Bureaus (EPB) at provincial and municipal levels are responsible for enforcing the regulations on air pollutants emission standards. The citizen reporting, Continuous Emission Monitoring System (CEMS), and on-site supervisory monitoring actions can become a trigger for the environmental monitoring departments under the EPBs to collect the data on pollution emission of non-compliant enterprises. Based on the evidence, the EPBs are able to take stronger enforcement measures, which are entitled by the new *'Environmental Protection Law'*, to regulate any non-compliance. During the process, the environmental monitoring department in the MEP asks local EPBs to report all cases promptly and in the meantime provides assistance on technical capacity and interpreting regulations. For more information, please refer to **Section 5** and **Section 8**.

Figure 4: The Policy Framework of the Air Pollution Prevention and Control in China



Source: Adapted from 'China Air 2015: Air Pollution Prevention and Control Progress in Chinese Cities', Clean Air Asia. Link: http://cleanairasia.org/wp-content/uploads/2016/03/ChinaAir2015-report.pdf (in Chinese)

Environmental standards are one of major policy measures that reduce air pollutant emissions and have played a key role in controlling the amount of pollutants emitted from the CFPPs. The following paragraphs will focus on the standards related not only to air pollutants but also energy efficiency, water consumption and fly ash management.

3.1. Emission mission standards for air pollutants

With environmental problems becoming increasingly prominent, the old air pollutant emissions standards fell behind the social development and growing demand for improved environmental quality. In addition, more effective environmental regulation needs real-time monitoring data on pollutants emissions, which CFPPs were not required to provide according to the old standards. By working with the Environmental Protection Research Institute under the Guodian Science and Technology Research Institute, China Academy of Environmental Sciences took a lead in drafting the new standards. The two entities are government-affiliated and provide policy and technical supports for law and regulation making. The latest Chinese '*Emission Standards of Air Pollutants for Thermal Power Plant' (GB13223-2011)* [22]were therefore adopted by MEP in July 2011 and took effect on January 1st 2012, with specific effective dates for different categories of plants and air pollutants.

Table 5: Emissions Standard of Air Pollutants for Coal-fired Power Plants

Category	PM	SO_2	NOx	Mercury
	(Unit: mg/m³)			
New Plants	30	100 (200[a])	100	0.03
Existing Plants	30	200 (400 [a])	100 (200[b])	0.03
Special Emission Limit [c]	20	50	100	0.03

Adapted from 'Emission Standards of Air Pollutants for Thermal Power Plant' (GB13223-2011)
[a] Plants located in the Guangxi Zhuang Autonomous Region, Chongqing Municipality, Sichuan Province and Guizhou Province implement this limit;
[b] For boilers using W-shaped flame furnace, existing circulating fluidized bed, operating or getting environmental impact report approval before December 31st, 2003;
[c] The specific geographical scope and time for the implementation of the special emission limit of air pollutants shall be prescribed by the MEP under the guidance from the State Council.
Note on timeline: Since July 1st, 2014, the existing coal-fired power boilers to implement the emission standards of PM, SO_2 and NOx specified in the Table; Since January 1st, 2012, the new coal-fired power generation boiler to implement the emission standards of PM, SO_2 and NOx specified in the Table; Since January 1st, 2015, coal-fired boilers will implement the mercury emission limits specified in the Table.

Compared to the prior *GB13223-2003* emission standards[23], the current 2011 version has more stringent limits for particulate matter, sulfur dioxide, nitrogen oxides and mercury emission limits. In summary, the emission standards in the 2011 version have the following four changes:

1) Emission limits have been greatly strengthened, sulfur dioxide emissions compared to the previous version are reduced around 50%, and nitrogen oxides down from 450 mg/m^3 down to 100 mg/m^3, a reduction rate of nearly 78%;

[22] Emission Standards of Air Pollutants for Thermal Power Plant (GB13223-2011). MEP 2011. Link: http://kjs.mep.gov.cn/hjbhbz/bzwb/dqhjbh/dqgdwrywrwpfbz/201109/W020130125407916122018.pdf (in Chinese)

[23] Emission Standards of Air Pollutants for Thermal Power Plant (GB13223-2003). MEP 2003. Link: http://kjs.mep.gov.cn/hjbhbz/bzwb/dqhjbh/dqgdwrywrwpfbz/200401/W020110127387986915138.pdf (in Chinese)

2) It distinguishes between the application of emission limits, implementing stricter emission limits in densely populated, economically developed key cities, and implementing less strict standards for economically developing and remote areas;
3) For the first time, the difference between new and existing power plant boilers is specified, with stricter emission limits for new capacity, setting an entry level by considering technological progress;
4) The importance of mercury and its compounds is brought forward on the agenda due to their harmful health impacts, *GB13223-2011* limits mercury and its compounds emissions for coal-fired power plants for the first time.

Recently, the Chinese government is promoting ultra-low-emission retrofitting of CFPPs, namely through multi-pollutant and efficient collaborative control technology, requiring PM, SO_2 and NOx emissions from CFPPs to be as low as the level of natural gas fired power plants, i.e.PM levels limited to 10 or even 5 mg/m^3, SO_2 to 35 mg/m^3 and NOx not exceeding 50 mg/m^3.These ultra-low emission limits have been adopted by several municipalities and provinces including Shanghai, Jiangsu and Zhejiang in the east, Shanxi province in the west, and in Guangzhou city as well. Refer to Section 9 for more information on ultra-low-emission CFPPs.

- Historical Emissions Standards of Air Pollutants for CFPPs

The emission standards for air pollutants were initiated in the early 1970s, and back then there were no specific emission standards for thermal power plants. In 1973, China promulgated the *'Industrial Three Wastes Emission Standards' (GBJ4-73),* for waste exhaust, waste water and solid waste. This national standard included air pollutant emissions standards from thermal powerfor the first time, specifically, CFPPs since there were no natural gas fired power plants. Emission rates of particulate matter were targeted, and SO_2, NOx and mercury were not included (**Table 6**).

Table 6: Historical Emissions Standards of Air Pollutants for Coal-fired Power Plants

Category (*Unit: mg/m³*)	**PM**	**SO_2**	**NOx**	**Mercury**
GBJ4-73	By emission rate (kg/h)according to chimney height	None	None	None
GB13223-1991	150-3,300 [a]	By allowed amount calculated according to chimney height and dispersion conditions	None	None
GB13223-1996	150-2,000 [b]	1,200-2,100 [c]	650-1,000 [d]	None
GB13223-2003	50-600 [e]	400-2,100 [e]	450-1,500 [e]	None
GB13223-2011	20-30	50-200	100-200	0.03

[a] *Depending on boiler capacity, years in operation, dust collector type and location of plant;*
[b] *Depending on fuel quality, boiler type &capacity, years in operation, dust collector type and location of plant;*
[c] *The emission limit for third-phase plants (operation after January 1st, 1997, depending on fuel sulfur content; the first- and second-phases were calculated according to chimney height and dispersion conditions;*
[d] *Depending on boiler type, only applied to boiler capacity above 1,000 t/h;*
[e] *Depending on plants' years of operation and implementation timeline;*

The emission standards of air pollutants for thermal power plants were created first in 1991 and amended in 1996, 2003 and 2011. In 1991, the State Environmental Protection Department released the *'Emission Standards of Air Pollutants for Coal-fired Power Plants' (GB13223-1991)*, replacing the standards related to thermal power plant air pollutant discharge standards in *GBJ4-73*. However, the 1991 standards did not include the emissions of NOx and mercury. SO_2 emissions were regulated by the allowed amount calculated by chimney height and dispersion conditions, without setting concentration limits. In 1996, the standard was revised and changed its name to *'Emission Standards of Air Pollutants for Thermal Power Plant '(GB13223-1996)*, with a PM limit similar to that of the 1991 standards, but SO_2 and NOx were included by allowed concentration levels, consistent with the *'Law on Air Pollution Prevention and Control'*. Seven years later, the 1996 standard was upgraded to *GB13223-2003*, with significant improvements in the standards especially for PM and SO_2, both of which became as low as one third of the 1996 permitted levels. Also, the 2003 revisions divided power generators into three different phase-based categories to comply specific emission standards based on their starting year of operation, with stricter limits for new units; the first phase was defined as thermal power plants operated or EIA approved before December 31, 1996, the second phase referred to plants operated or EIA approved the after January 1st, 1997 while before December 31st, 2003, and the third phase for plants operated or EIA approved after January 1st, 2004. The 2011 revisions tightened the emission limit values for PM, SO_2, NO_x and mercury to the point that they are stricter than comparable laws in the US, EU, and Canada[24].

- The basis for arriving at the *GB13223-2011*: Why setting a high target?

The *GB13223-2011* has been discussed extensively not only within China, but also internationally, since it sets a high bar for the CFPPs compared to its predecessor and the emissions standards in the major economies. The overarching objectives of the *GB13223-2011* are to 1) strengthen new thermal power plants' pollutant emission control and efforts to reduce the amount of new pollutants emissions; 2) reduce the existing thermal power plants' pollutant emissions and achieve total reduction; 3) further promote thermal power plants to install flue gas desulfurization and denitrification devices, and improve the stable and efficient operation; 4) further promote thermal power plants to improve dust removal efficiency; 5) expand the environmental protection industry's development through the implementation of new standards.

According to the preparation instructions for *'Emission Standards of Air Pollutants for Thermal Power Plant' (Second consultation draft)*[25], it is necessary to revise the *GB13223-2003* emission standards, and this draft illustrates the basis of arriving at the *GB13223-2011* as follows:

1) To meet the higher requirement from the governmental environmental protection plan

The national *11th Five-Year Plan* proposed a binding target of 10% reduction of SO_2 emissions, and the *11th Five-Year Plan for National Environmental Protection* proposed to ensure that SO_2 emission reduction targets could be met, and the CFPPs' desulfurization and denitrification could be further promoted. The *Plan* also emphasised the implementation of acid rain and SO_2 pollution control planning by focusing on control of elevated source of SO_2 and NOx emissions, and the improvement of ambient air quality through control particulate matters emissions

[24] China's War on Air Pollution. Link: http://www.powermag.com/chinas-war-on-air-pollution/?pagenum=3.

[25] The preparation instructions for '*Emission Standards of Air Pollutants for Thermal Power Plant'* (Second consultation draft), MEP 2011. Link: http://www.zhb.gov.cn/gkml/hbb/bgth/201101/W020110120352208669465.pdf

especially $PM_{2.5}$. The more populated and polluted regions such as BTH, YRD and PRD were recognised as the key regions for more extensive cooperation in regional air pollution control. Thus, environmental protection work, especially the control of air pollutants from thermal power plant had been put forward higher requirements.

2) To balance the power sector development and environmental health

In 2007, China's thermal power SO_2, NOx and PM emissions were 12.59 million tons, 8.4 million tons and 2.97 million tons. According to the analysis done by the new standard preparation team, they took into consideration of China's projected total economic output in 2020, the minimum installed capacity per capita, as well as the fact that the Chinese power structure will continue to maintain the reliance on coal-fired units for quite some time. They anticipated that by 2015 and 2020 China's thermal power installed capacity would reach 1,000 GW and 1,200 GW. In accordance with the old emission control level (*GB13223-2003*), the SO_2, NOx and PM emissions from thermal power plants in 2015 would reach 9.93 million tons, 11.16 million tons and 2.81 million tons respectively, which comparing with 2010, SO_2 would increase by 1.34 million tons, NOx by 2.51 million tons, and 0.27 million tons for PM emissions. Specifically, for mercury emissions, by 2015 the total emissions would amount to 359 tons. And the trend for all the pollutants by 2020 would be still increasing. The team therefore concluded that if the new emission standards are not introduced, the emissions of thermal power pollutants will continue to increase, and the impact on the ecological environment will become more and more serious. They also pointed out that China had also been aware that the country must avoid to take the industrialized countries' development path of 'pollution first, abatement later', and increase pollution control efforts in a quicker pace to ensure public health to be protected.

3) Thermal power plant air pollution control technology has made substantial progress

Since the implementation of *GB13223-2003* on January 1st 2004, emissions of air pollutants from China's thermal power plant have been controlled at a certain level and technological progress of air pollution control technologies have been promoted. As of the end of 2008, the thermal power capacity with installed desulfurization facilities reached 363 GW, accounting for 60.4% of the national thermal power installed capacity. The 2003 standard also pushed the development of low-nitrogen combustion technology for newly built large-scale coal-fired plants, and for building flue gas denitrification in the key regions. Also, a number of existing thermal power plants by then had combined with technological transformation to install low-nitrogen burners. China's power industry had been vigorously promoting the ESP technology and began to export the ESP equipment. The development of these control technologies provided technical support for improving the emission control requirements of air pollutants in thermal power plants and set the basis of implementing the more stringent new standard.

The MEP actually had released two versions of the consultation draft in 2009 and 2011 respectively, and compared to the first version[26], the emissions limits in the second version consultation draft were more ambitious and simple; for example, the limits of SO_2 and NOx for

[26] The preparation instructions for '*Emission Standards of Air Pollutants for Thermal Power Plant'* (First consultation draft), MEP 2009. Link: http://www.mep.gov.cn/gkml/hbb/bgth/200910/W020090713566703031134.pdf

new plants in the second version were only half of that in the first version consultation draft, and the number of categories for existing plants differentiation were reduced.

One of the main purposes of the *GB13223-2003* standard was to vigorously promote the emission control of China's thermal power SO_2, and the implementation of efficient flue gas desulfurization equipment installation. Taking into account the lack of operating desulfurization units and management experience of the actual situation, the development of the emissions limit was more relaxed. After several years of development, desulfurization device operating experience, management experience was more mature, so the 2011 revision developed more stringent emission limits in considering the desulfurization efficiency that the FGD technology can achieve. For the details on the determination and formulation basis of *GB13223-2011*, **Table 7** summarizes the basis by different air pollutants category.

Table 7: Determination and Formulation Basis of Pollutant Discharge Limit in *GB13223-2011*

Air Pollutants	Category of Plants	Determination and formulation basis
SO_2	New plants: 100 (200 [a]) mg/m^3	The new CFPPs as required should be above 300 MW with better performance and higher efficiency, having conditions to use advanced energy efficient production technology and advanced FGD technology. Also, in order to avoid the secondary transformation of the new power plant, the emission limit should be more stringent. The new standard's preparation instruction referred to the EU, Japanese and American standards, the Chinese one was set stricter than those foreign counterparts.
	Existing plants: 200 (400 [a]) mg/m^3	For the existing CFPPs, since *GB13223-2003* standard till the release of the 2011 standard, the FGD deployment had achieved a high penetration rate, emission limits were set according to the actual deployment situation, environmental requirements and technology development status.
NOx	New plants: 100 mg/m^3	The new CFPPs will have conditions to use advanced energy efficient production technology and advanced low-nitrogen combustion technology and flue gas denitrification technology. Also, in order to alleviate acid deposition, atmospheric visibility reduction, hazy weather caused by atmospheric NOx pollution, it is necessary for the new CFPPs to adopt more stringent emission limits, which are even stricter than the EU and American counterparty standards.
	Existing plants: 100 (200 [b]) mg/m^3	For the existing CFPPs, since *GB13223-2003* standard had requested plants in operation after January 1st, 2004 to set aside space for flue gas denitrification equipments, those plants had the condition to install denitrification device. For units completed before December 31st, 2003, emission limits were set according to the actual situation, environmental requirements and existing technology, at the level of 200 mg/m^3.
PM	New plants: 30 mg/m^3	In the formulation of PM emission limits, the drafting team of the new standard mainly considered the following aspects: a) new power plants should be installed with simultaneously desulfurization device, PM removal efficiency after FGD can be further improved; b) new power plants have the conditions of installing ESP or bag filter to achieve high dust removal efficiency; c) from the experience of the United States, Japan and the EU, they all had put forward stringent requirements for new power plants. China's standards are the same as the EU' emission limits for new plants.

	Existing plants: 30 mg/m^3	For the existing CFPPs, since *GB13223-2003* standard till the release of the 2011 standard, ESP had been deployed on almost all generation units, and even some 600 MW units were equipped with bag filter, plus the electronic bag dust collector had been developing for nearly 10 years and become technically mature to realize the emission limit in the 2011 standard even for the existing plants.
Mercury	0.03 mg/m^3	GB13223-2003 standard did not set mercury emission limit, in order to support the compliance of international convention, the 2011 revision introduced the mercury emissions limit, through the study of emissions standards for thermal power plants in the United States, the EU and Germany, the mercury emission limit for thermal power plants in China was determined to be 0.03 mg/m^3, which is the same as the German *'Large Combustion Plant Ordinance (GFAVO)'* 2004 revision.

Adapted from 'Emission Standards of Air Pollutants for Thermal Power Plant' (GB13223-2011) and preparation instructions for 'Emission Standards of Air Pollutants for Thermal Power Plant' (Second consultation draft). [a] *Plants located in the Guangxi Zhuang Autonomous Region, Chongqing Municipality, Sichuan Province and Guizhou Province implement this limit;* [b] *For boilers using W-shaped flame furnace, existing circulating fluidized bed, operating or getting environmental impact report approval before December 31st, 2003;*

- The basis for the Special Emission Limit in the *GB13223-2011* for the Key Regions

The Special Emission Limit first appeared in the *'Guiding Opinions on Improving Regional Air Quality in Promoting Air Pollution Joint Control'* issued by the MEP in May 2010 [27]. In order to implement this *Guiding Opinions*, the *GB13223-2011* includes the Special Emission Limit and requires the specific geographical scope and time period for the implementation of the special emission limits to be prescribed by the administrative department of environmental protection under the guidance of the State Council. The Key Regions to implement special emission limits was later delineated by the MEP in 2013 (refer the to Section 4 for more information).

According to the *'Interpretation of Newly Released Emission Limit for Air Pollutants'* from the MEP [28], the Key Regions are mainly areas where the land has been intensively developed, the carrying capacity of the environment already weakened, and the ecological environment is fragile. In these areas, serious environmental pollution problems are likely to occur. Therefore, the Key Regions must be given priorities in environmental protection, using the most viable and most efficient pollution control technology to achieve a more stringent level of pollutant discharge, that is, to implement Special Emission Limits. The Special Emission Limit first appeared and were implemented when an outbreak of blooms in Taihu Lake happened in 2007, and the State Council requested the implementation of Special Emission Limit on the discharge of water pollutants in the key river basins in 2008. Currently, the implementation of Special Emission Limit for air pollutants has been expanded to not only power industry, but also steel, cement, chemical industries and among others

The development of Special Emission Limit is generally based on advanced and feasible technologies, which are more affordable to the Key Regions, since they tend to be more industrialised and more accessible to advanced technologies. Regarding the overarching basis of choosing certain technologies to comply, the focus of the MEP is to consider environmental

27 Notice of the General Office of the State Council on the Promotion of Regional Air Quality Guidance on the Promotion of Air Pollution Prevention and Control by the MEP, May 2011. Link: http://zfs.mep.gov.cn/fg/gwyw/201005/t20100514_189497.htm (in Chinese)

28 Interpretation of Newly Released Emission Limit for Air Pollutants. MEP, December 2013. Link: http://www.mep.gov.cn/gkml/hbb/qt/201312/W020131227664353210394.pdf (in Chinese)

benefits and social benefits after the implementation of the standards. The Key Regions need more stringent emission standards to achieve the desired environmental quality standards. Setting Special Emission Limit, on one hand increases the control of pollutant discharge in environmentally sensitive areas and raises the environmental access thresholds in these areas; on the other hand, promotes the development of more stringent local emission standards.

3.2. Standards relating to energy efficiency and water conservation

The standards related to energy and water saving are reflected in the following table, revised according to the *'Energy Conservation Code for Design of Thermal Power Plants' (GB/T 51106-2015)* and other relevant standards.

Table 8: Energy and Water Saving Requirements for Thermal Power Plants

Category	Requirements	Detail Indicators
Coal saving	**Boiler** Thermal efficiency higher than 88%-94%[a]	Exhaust temperature; Fly ash combustible material; Slag combustible material; Air preheater air leakage rate; Excess air ratio, etc.
	Turbine Turbine heat rate less than 7258kJ/kWh-8050kJ/kWh[b]	High-pressure and medium-pressure cylinder efficiency; Main and reheat steam temperature and pressure; Super heater and reheater cooling water flow; Condenser vacuum; Vacuum tightness; Condenser and heater end difference; Degree of undercooling of condensate; Water supply temperature, etc.
Plant electricity saving	**Plant electricity rate** Electrical equipment selection should be consistent with the national equipment energy efficiency limit and energy saving evaluation index	Power consumption rate of coal pulverizer, mill exhauster, primary air fan, induced drag fan, forced fan, circulating water pump, condensate extraction pump, water-feeding pump, ash remove system, coal transportation, desulfurization, etc.
Water saving	**Water Consumption** Design water consumption of thermal power plant less than $0.8m^3/(s\cdot GW)$-$0.06\ m^3/(s\cdot GW)$[c]	Whole plant reuse water rate; Boiler water supply rate; Circulating water concentration ratio; Chemical self-water consumption rate, etc.

[a]*Thermal efficiency due to different conditions has different requirement, different conditions including fuel type, combustion method and boiler rated evaporating capacity. More detail about boiler standards per 'Economical Operation of Industrial Boilers' (GB/T 17954-2007).*
[b]*Turbine heat rate due to different conditions has different requirement, different conditions including unit type, unit parameter and feed pump drive mode.*
[c]*Requirement, different conditions including unit cooling method, unit rated power and different process approaches. More detail about water consumption standards per 'Guide for Water Saving of Thermal Power Plant' (DL/T 783-2001).*

The MEP released the notice *'Full Implementation Plan of Ultra-Low-Emission Coal-Fired Power Plants and Energy-Saving Retrofitting Program'* at the end of 2015, aiming to accelerate the progress of CFPPs in achieving a nationwide ultra-low emission standard and upgrading necessary energy conservation measures[29]. The Plan mandated that all the new CFPPs should have a capacity above 600 MW, employ ultra-supercritical generation units, and the average coal consumption per unit of power generation should be less than 300 gce/kWh.

[29] Notice on 'Full Implementation Plan of Ultra-Low-Emission Coal-Fired Power Plants and Energy-Saving Retrofitting Program' December 11th 2015, MEP. Link:http://www.mep.gov.cn/gkml/hbb/bwj/201512/t20151215_319170.htm (in Chinese)

3.3. Standards relating to wastewater discharge

The general standard for compliance of the wastewater from the CFPPs is the *'Integrated wastewater discharge standard' (GB8978-1996)*. The *Grade III* level is the minimum requirement, and local authorities are allowed to have more stringent requirements. The major pollutants are listed in **Table 9**.

Table 9: Wastewater Discharge Standard for CFPPs

Pollutants (mg/L)	**Grade I**	**Grade II**	**Grade III**
pH	6-9	6-9	6-9
SS	70	150	400
BOD_5	20	30	300
COD	100	150	500
Fluoride	10	10	20
Sulphide	1.0	1.0	1.0
NH_3-N	15	25	-

Adapted from the 'Integrated wastewater discharge standard' (GB8978-1996)

Specifically, the *'Discharge Standard of Wastewater from Limestone-Gypsum FGD System in Thermal Power Plants' (DLT 997-2006)* sets standards for wastewater from Flue Gas Desulfurization (FGD) systems.

Table 10: Discharge Standard for Wastewater from FGD System

Pollutants	**Concentration Limit** (mg/L)
pH	6-9
SS	70
COD	150
Fluoride	30
Sulphide	1.0
Sulphate	2,000
Hg	0.05
Cd	0.1
Cr	1.5
As	0.5
Pb	1.0
Ni	1.0
Zn	2.0

Adapted from the Discharge standard of wastewater from limestone-gypsum FGD system in thermal power plants' (DLT 997-2006)

There is a hope from environmental authorities to push the idea of 'Zero Emission' CFPPs, not only to reduce the effluents discharge as little as possible, but also to increase the reuse of wastewater and save the total water consumption of CFPPs.

3.4. Standards relating to fly ash management

The ash producing entities must report and register the production, storage, flow, utilization and disposal of fly ash in accordance with the '*Law on the Prevention and Control of Environmental Pollution by Solid Wastes'* and the relevant provisions of the environmental protection department. A new and expanded CFPP project feasibility study report and the project application report will put forward a comprehensive utilization of fly ash program, and clarify fly ash utilization and disposal methods. The facilities' storage and transportation equipment for fly ash have to be designed, built and completed at the same time as the main project. Ash must be separated by wet versus dry, and the thickness of ash, and stored in the corresponding ash storage facilities.

New CFPPs should consider the potential use of fly ash, save land, prevent environmental pollution, and avoid the construction of permanent fly ash yard. If a fly ash yard has to be built, it can cover an area of no more than 3 years of ash storage design, and the location, design, construction and operational management of the fly ash yard has to comply with the *'Standard for Pollution Control on the Storage and Disposal Site for General Industrial Solid Wastes'*. Additionally, new power plants cannot discharge wet fly ash. The fly ash in the yard has to be strictly managed in accordance with the relevant provisions of the environmental protection department.

For existing CFPPs they have to improve the fly ash storage, loading and transportation systems, including facilities for processing, sorting, grinding and ash field comprehensive management. Existing wet ash dump yards should develop pollution prevention and control programs, and report to local municipal utilization of resources departments and environmental protection departments for record keeping.

Ash producing units have to provide convenient loading for extraction from ash yards in order to maintain safety of the ash fields and production sites. Additionally, fly ash must be transported by a closed tanker, and compliance with all environmental protection requirements is necessary to avoid pollution during transport.

3.5. Public perceptions to air pollution and coal power

Public understanding of air pollution has gone through many stages in China, with Beijing often acting as the most reported about example. Many citizens, especially those in the capital, were outraged when the US embassy in Beijing began tweeting air pollution data regarding $PM_{2.5}$ levels on twitter in 2008. Their anger, however, was not pointed towards the US Embassy, but at the misguidance and lack of air quality information that should be provided by the government. Prior to this, pollution had been called 'fog', and after a year of publishing data, a Chinese Foreign Ministry official asked for the American embassy to stop publishing the data for its insulting sovereignty of China. However, the public learned that the government not only was trying to cover up the data published by the US, but also had the capability to monitor $PM_{2.5}$ themselves long before the event. The government had not disclosed the $PM_{2.5}$ data monitored by the regulatory facilities. The public were outraged and quite a few social movements started by local environmental groups. Mr. Pan Shiyi, a well-known real estate tycoon began posting on his micro blog about air pollution and public knowledge, and others began to file applications to have municipal Environmental Protection Bureaus publish $PM_{2.5}$ data[30].The well-known 'airpocalypse' of 2012, when air pollution hit record highs, invoked disappointment in the lack of preemptive action to reduce air pollution in cities. As social media platforms became more widespread during this period, Chinese citizens became not only more aware of the air pollution, but also more active in pressuring the government and businesses to resolve the problem. This public involvement is understood to be a large reason why the government began to officially publish data in 2013 on air quality [31]. A 2015 study placed concern about air pollution as the second highest concern in China, and concern about water pollution as the third[32].

MEP and local EPBs are in charge of monitoring, reporting and publishing the Air Quality Index (AQI)[33]; in total, there are 367 cities/counties monitoring air quality, as of the beginning of 2017 the total number of monitoring stations are more than 5000 [34]. During red alerts, when AQI exceeds 300 for three days in a row, car use is strictly constrained; however, many citizens claim that more than just car use should be restricted, factories and coal burning facilities are the main causes and need to be closed as well [35]. Overall, in the past six years, awareness of air pollution and its sources have increased, especially in large cities. For instance, Beijing has not only experienced high amounts of pollution but also become an international spotlight for its AQI. This awareness has been bolstered by social media platforms such as WeChat and Weibo, leading to official government publication of data. The social movement and disclosure of air quality data all point to the clean air policy changes in the meantime.

Pubic movement should be one of the driving forces for the government to disclose more environmental quality data; however, the public care more about air quality and their health issues, not particular attention has been given to the emission standards of CFPPs.

4. Air Pollution Standards in Three Key Metropolitan Regions

Regional air pollution has drawn more and more attention in China in recent years, especially in the most populated three key regions: The Beijing-Tianjin-Hebei region (BTH), Yangtze River Delta region (YRD) and the Southern Guangdong Pearl River Delta region (PRD), since the cities within

[30] Outrage Grows Over Air Pollution and China's Response. Accessible at: http://www.nytimes.com/2011/12/07/world/asia/beijing-journal-anger-grows-over-air-pollution-in-china.html.

[31] How the internet is powering the fight against Beijing's dirty air. Accessible at: https://www.theguardian.com/environment/2012/apr/10/internet-beijing-dirty-air-pollution.

[32] Corruption, Pollution, Inequality Are Top Concerns in China. Accessible at: http://www.pewglobal.org/2015/09/24/corruption-pollution-inequality-are-top-concerns-in-china/.

[33] MEP Data Center. Link: http://datacenter.mep.gov.cn/index (In Chinese)

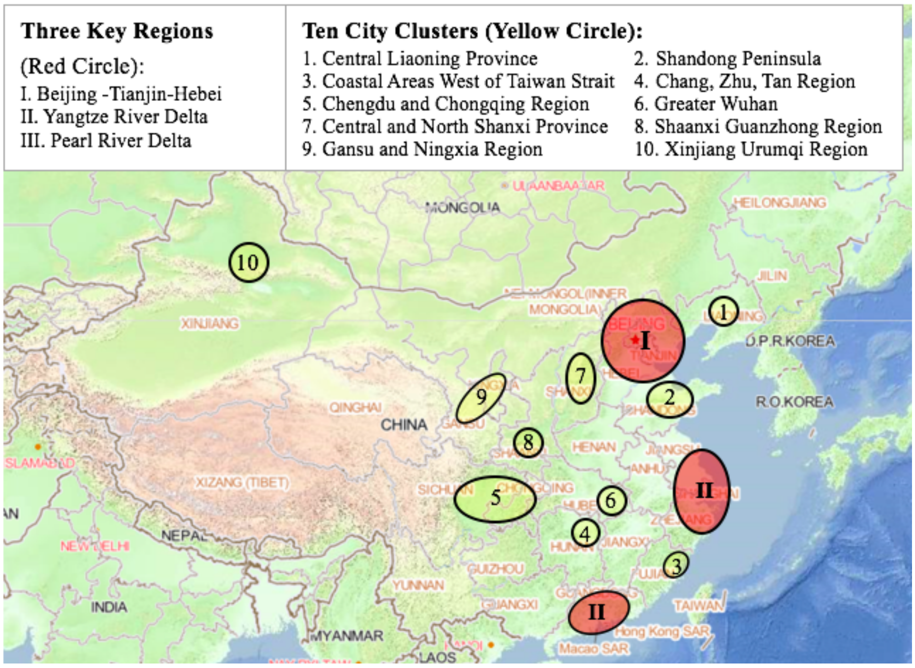
[34] Ministry of Environmental Protection: National Ambient Air Quality Monitoring Network has been completed. Link: http://news.xinhuanet.com/politics/2017-02/12/c_1120452280.htm (In Chinese)

[35] Beijing announces emergency measures mid fog of pollution. Accessible at: http://edition.cnn.com/2013/10/23/world/asia/china-beijing-smog-emergency-measures/.

these key regions suffer significant interactive impacts with each other and need cooperative mechanism to work together. These three regions have implemented extra regional efforts and policies regarding air pollution, including restrictions on vehicles, thermal power plants, large industries and other major sources of pollution.

To better improve regional air quality throughout metropolitan areas, the MEP issued the action of *'Joint Prevention and Control Plan of Air Pollution'* in 2011, which was first implemented in these three key regions during the period of the *12^{th} FYP*. This *Plan* aimed to establish a joint prevention and control system and ensure that all cities in the three key regions effectively improved their regional air quality and achieved air quality at or better than the *Grade II 'National Ambient Air Quality Standard' (GB 3095–2012)*, the detail figures from this standard can be seen in **Appendix 2**.

Figure 5: The Key Regions Identified for Intensive Regional Air Pollution Control



Source: Author's own analysis

In 2013, the State Council issued the *'Air Pollution Prevention Action Plan'* and gave a special emphasis on coal consumption, specifically stating that the share of coal in total energy consumption should fall below 65% by 2017. BTH, YRD and PRD regions were specified to strive to achieve negative growth in total coal consumption by gradually increasing their proportion of external transmission reception, increasing natural gas supply, increase non-fossil energy intensity and other measures to replace coal[36]. In order to implement the *'Action Plan'* and the '*12^{th}FYP on Air Pollution Prevention and Control in Key Regions'* , the State Council also identified the key regions as shown on **Figure 5**, stipulating them to implement the Special Emission Limit as required in **Table 5** [37].

[36]Air Pollution Prevention Action Plan, State Council Order, September 13^{th} 2013. Link: http://www.gov.cn/zhengce/content/2013-09/13/content_4561.htm (in Chinese)

[37] Notice on the 'Implementation of Special Emission Limits for Air Pollutants'. February 27^{th} 2013, MEP. Link:http://www.zhb.gov.cn/gkml/hbb/bgg/201303/t20130305_248787.htm (in Chinese)

Other than seeking to reduce coal consumption, limit new capacity and encourage renewables, the air pollution standards in these three regions have evolved as the air pollution issues become more evident.

4.1.Standards in Beijing-Tianjin-Hebei Region

Under the *'Air Pollution Prevention Action Plan'*, the governments at all levels also announced their implementation details. In the BTH region, there are a cooperative implementation details under the *'BTH and Surrounding Areas to Implement Air Pollution Control Action Plan'*.

- **Beijing**

Beijing has its own *'Clean Air Action Plan 2013-2017'*, through which the local air pollution standards for coal-fired boilers were tightened in 2015 for all the three air pollutants: PM, SO_2 and NOx (**Table 11**).

Table 11: Emissions Standard of Air Pollutants for Coal-fired Boilers in Beijing

Category	Timeline	PM	SO_2	NOx	Mercury
		(Unit: mg/m^3)			
New Boilers	Before March 31st , 2017	5	10	80	0.0005
	After April 1st, 2017	5	10	30	0.0005
Existing Boilers	Within high-polluted fuel forbidden area; Before March 31st , 2017	10	20	100	0.03
	Within high-polluted fuel forbidden area; After April 1st , 2017	5	10	80	0.0005
	Outside high-polluted fuel forbidden area; Since July1st*, 2015*	10	20	150	0.03

Source: Boiler Air Pollutant Discharge Standard (DB11/139-2015, Beijing Local Standard), Link: *http://www.bjepb.gov.cn/bjepb/resource/cms/2015/06/2015060311453388513.pdf* *(in Chinese)*

In addition to tightened standards, reduction of coal consumption in Beijing was also on the agenda, all of the four CFPPs in Beijing were scheduled for gradual closure. One closed in 2014, two in 2015, and by the end of 2016, the last CFPP was offline and four natural gas combined heat/power cogeneration plants took the role of CFPPs. This strategy of switching coal to gas shows the capital city's resolution in controlling the air pollutants from CFPPs.

- **Tianjin**

Similar to Beijing, there is no specific emission standard for thermal power plants in Tianjin, instead the standard for compliance is called *'Emission Standard of Air Pollutants for Boilers' (DB12/151-2016)*, last updated in 2016, replacing the *DB12/151-2003*.

Table 12: Emissions Standard of Air Pollutants for Coal-fired Boilers in Tianjin

Category	Timeline	PM	SO_2	NOx	Mercury
		(*Unit: mg/m³*)			
New Boilers	Since the implementation of the Standard on August 1st , 2016	20	50	150	0.0005
Existing Boilers	Within high-polluted fuel forbidden area; After January 1st , 2018	No CFPPs allowed to exist			
	Within high-polluted fuel forbidden area; Before December 31st , 2017	30	200	400	0.0005
	Within high-polluted fuel forbidden area; After January 1st , 2018	No CFPPs allowed to exist			
	Outside high-polluted fuel forbidden area; Before December 31st , 2017	30	200	400	0.0005
	Outside high-polluted fuel forbidden area; After January 1st , 2018	30	100	200	0.0005

Source: Emission Standard of Air Pollutants for Boiler' (DB12/151-2016)Tianjin Local Standard), Link: http://att.teda.gov.cn/hjbhj/upload/UpLoadPath/2016/8/17/628795888622fb-3fb7-4f57-8236-3c4105bef3e0.pdf *(in Chinese)*

As seen from the above table, all the emission limits for PM, SO_2 and NOx in Tianjin local standards are generally less strict than that of the Beijing local standards. While within the high-polluted fuel forbidden area, Tianjin has the plan to remove all CFPPs after January 1st, 2018. For new boilers in Tianjin, the NOx emission limit standard is actually 50 mg/m³ higher than the national standard for CFPPs, and in this case the latter prevails.

The intention of introducing this local standard for boilers was to implement the *'Law on Air Pollution Prevention and Control'* and *'Tianjin Air Pollution Control Regulations'*, improving the air quality in Tianjin and neighbouring regions.

- **Hebei province**

Although adjacent to Beijing and Tianjin, Hebei still has many people living below the national poverty line, and the province's per capita GDP is far behind that of Beijing and Tianjin. Hebei's provincial GDP is among the Top 10 in China, but its economy is highly dependent on heavy industries such as steel, cement, coal power and chemical production. This economic structure in Hebei has created major sources of industrial pollution in the BTH region and has been under huge pressure to reduce air pollutants especially in recent years since they need to think more of how to balance the economic growth, environmental pollution and possible increase of unemployment from clean air policy and actions. Due to blame of the Hebei being the major cause of the regional air pollution, Hebei government has been under huge pressure and made commitment in air pollution control, and therefore set more ambitious emission standard.

Hebei Provincial EPB released *'Coal-fired Boiler NOx Emission Standards'* in 2014 to strengthen the air pollution control technology support and improve air quality. As for existing coal-fired boilers, the NOx concentration limit was set at 300 mg/m^3, and new boilers were set at 200 mg/m^3. While in the middle of 2015, Hebei EPB released the more stringent *'Emission Standards of Air Pollutants for CFPPs'* and set the official effective implementing date as January 1st, 2016.

Table 13: Emissions Standards of Air Pollutants for CFPPs in Hebei

Boiler Capacity	Sub-category	PM	SO_2	NOx	Mercury
		(Unit: mg/m^3)			
Boiler output over 65t/h	Fueled by pulverized coal	10	35	50/100 [a]	0.03
	Fueled by coal gangue, slime, washed coal and other low calorific value coal	20	50	100	0.03
	With grate furnace and stoker furnace	30	200	200	0.05
Boiler output below 65t/h	Fueled by pulverized coal;	20	50	100	0.03
	Not fueled by pulverized coal	30	200	200	0.05

[a]*For boilers using W-shaped flame furnace and existing circulating fluidized bed*
Source: Emission Standard of Air Pollutants for CFPPs (DB13/ 2209—2015), Hebei Local Standard), Link: *http://www.lfhbj.gov.cn/UploadFiles/kjbz/2015/9/201509061115477983.pdf* *(in Chinese)*

In March 2015, the Hebei provincial government started a special action upgrading coal-fired power plants to ultra-low emission plants, with the goal that all coal-fired generating units would implement retrofitting and air pollutants would meet ultra-low emission requirements by the end of 2015 [38], but this ambitious ultra-low emission target was far from being achieved, and the CFPPs are still complying with the standards in **Table 13** according to Hebei EPB's website.

4.2. Yangtze River Delta Region

- **Shanghai**

To implement the *'Shanghai Air Pollution Prevention Ordinance'* and the *'Shanghai Clean Air Action Plan (2013-2017)'*, strengthen the emission control of air pollutants from CFPPs, promote technical progress of the industry, and improve the environmental quality and human health, Shanghai released the *'Emission Standard of Air Pollutants for Coal-Fired Power Plant' (DB31/963-2016)* in January 2016. As displayed in **Table 14**, the emission standards are set the same as ultra-low emissions standards, showing Shanghai's ambition to comply with the policy requirement and achieve a high environmental performance of its CFPPs.

[38] This year's coal-fired power plants in our province will all achieve 'ultra-low emissions', Hebei Governmental Website. Link: http://www.hebei.gov.cn/hebei/11937442/10761139/12629528/index.html (in Chinese)

Table 14: Emissions Standard of Air Pollutants for Coal-fired Power Plants in Shanghai

Category	Implementation Date	PM	SO_2	NOx	Mercury
		(*Unit: mg/m³*)			
New CFPPs	January 29th 2016	10	35	50	0.03
Existing public CFPPs (600MW~)	September 1st 2016				
Existing public CFPPs (~600MW)	September 1st 2017				
Existing non-public CFPPs (600MW~)	January 1st 2017				
Existing non-public CFPPs (~600MW)	January 1st 2018				

Source: 'Emission Standard of Air Pollutants for Coal-Fired Power Plant' (DB31/963-2016) Link: http://www.sepb.gov.cn/fa/cms/shhj//shhj2024/shhj2038/2016/02/91580.htm (in Chinese)

The schedule of implanting the new standard differs according to the utility ownership namely public or non-public, and also by the installed capacity, with 600 MW being the threshold. Prior to the required date of implementation, all the existing CFPPs ought to comply with the national standard *GB13223-2011* (see **Table**).

- **Zhejiang and Jiangsu**

There are no specific local standards for Zhejiang and Jiangsu provinces in terms of air pollutants from CFPPs, the two provinces implement the national standard.

The MEP released the notice at the end of 2015 by the name of *'Full Implementation Plan of Ultra-Low-Emission Coal-Fired Power Plants and Energy-Saving Retrofitting Program'*, aiming to accelerate the progress of CFPPs in achieving a nationwide ultra-low emission standards and necessary upgrading measures for energy conservation purposes[39].

Zhejiang and Jiangsu are both within the first group to achieve the ultra-low emission standards, with PM, SO_2 and NOx below 10, 35 and 50 mg/m^3 respectively, and the required time line according to the *Implementation Plan* is to complete the ultra-low emission upgrade by the end of 2017. Zhejiang currently is moving much faster and is expected to reach the ultra-low emission level by the middle of 2017, while Jiangsu might delay the process to the end of 2018[40].

4.3.Pearl River Delta Region

The emissions standards for CFPPs has been following the national standard for thermal power plants, although there was local *'Emission Standard of Air Pollutants for Boilers' (DB44/765-2010)*

---

[39] Notice on 'Full Implementation Plan of Ultra-Low-Emission Coal-Fired Power Plants and Energy-Saving Retrofitting Program' December 11th 2015, MEP. Link:http://www.mep.gov.cn/gkml/hbb/bwj/201512/t20151215_319170.htm (in Chinese)

[40] Nationwide campaign to achieve ultra-low emissions for coal-fired power plants. Link: http://paper.people.com.cn/zgnyb/html/2015-04/20/content_1556499.htm (in Chinese)

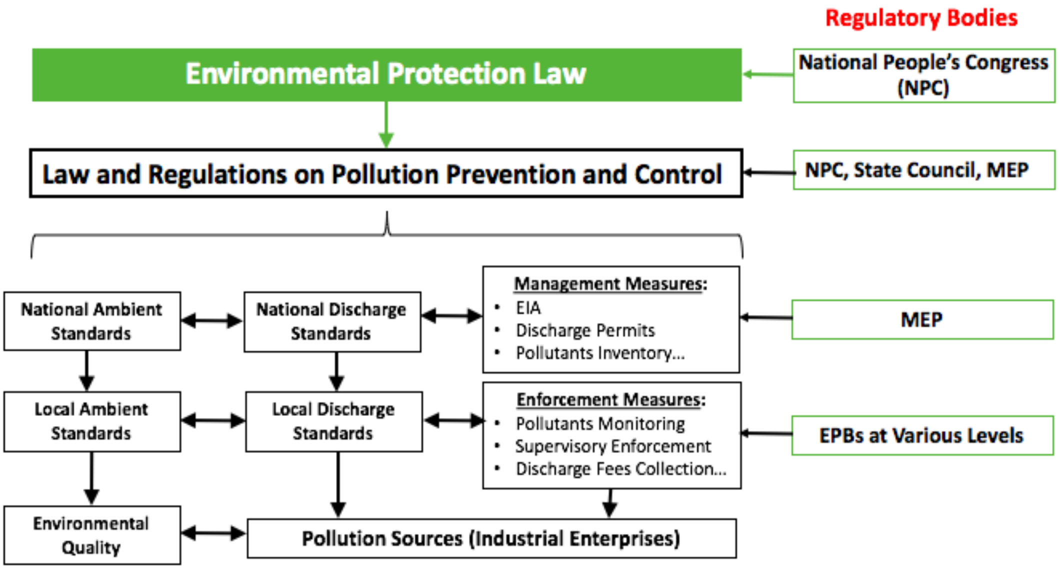
released back in 2010 [41], the limit in this local standard is significantly lower than the latest 2011 national standard *GB13223-2011*.

According to the *'Guangdong Province Air Pollution Prevention and Control Action Plan (2014-2017)'* released in February 2014 [42], starting from July 1st 2014, all the CFPPs in the Pearl River Delta region were to comply with the Special Emission Limit in the national standard, with PM, SO_2 and NOx below 20, 50 and 100 mg/m^3 respectively.

5. The State of Compliance with Existing Environmental Standards

The national regulatory framework for environment is composed of a series of environmental laws, regulations, standards and measures, as progressively formulated in **Figure 6**. In terms of compliance to the pollutants discharge standards, this environmental regulatory system has played an important role in controlling industrial pollution.

Figure 6: China's National Regulatory Framework for Environmental Management



Source: Author's analysis

The formulation and execution of China's environmental laws and regulations is led by the National People's Congress, the State Council and the MEP. The national pollutants discharge standards are formulated by the MEP by considering the National Ambient Standards, being realized by the management measures; in terms of enforcing the the local standards, EPBs at various levels are responsible for the enforcement measures through the specific four-tiered organizational system namely national, provincial, municipal and county levels. The detail organizational structure of a typical Chinese provincial EPB is summarized in **Figure 7**.

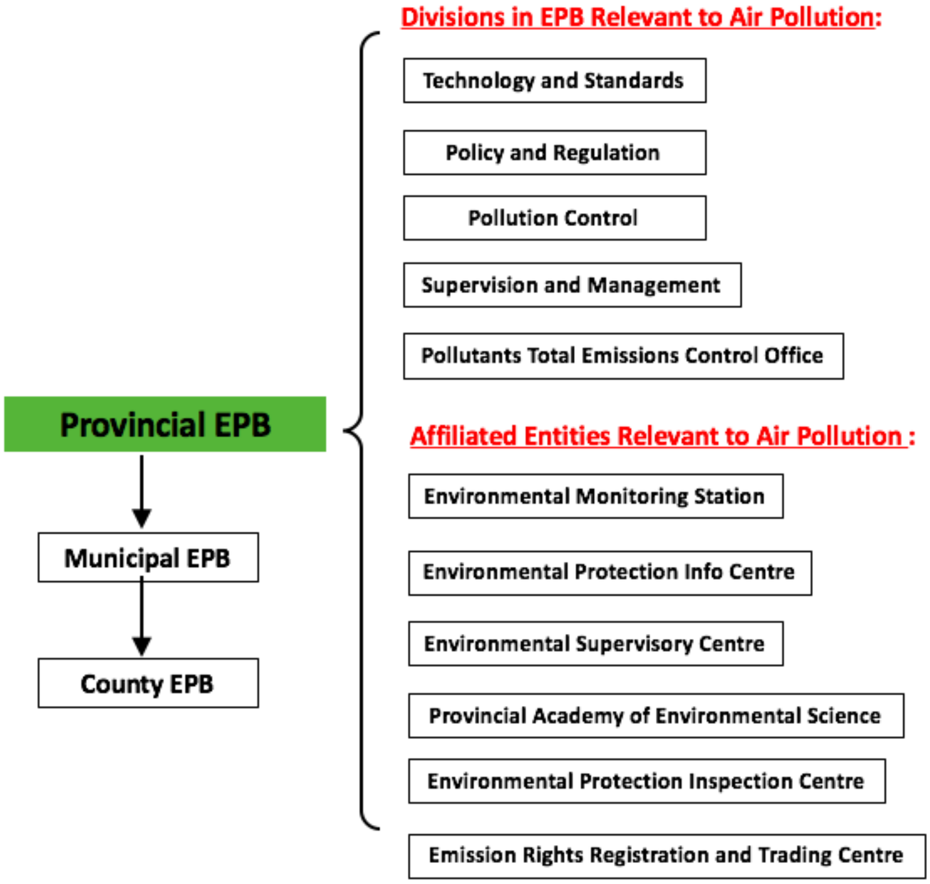
[41] Emission Standard of Air Pollutants for Boilers' (DB44/765-2010). Link: http://www.gzepb.gov.cn/zwgk/fgybz/dqwywpfbz/201412/P020141223635139681584.pdf (in Chinese)

[42] Guangdong Province Air Pollution Prevention and Control Action Plan (2014-2017). February 07th 2014, Guangdong Provincial Government. Link: http://zwgk.gd.gov.cn/006939748/201402/t20140214_467051.html (in Chinese)

The supervisory monitoring, implemented by provincial EPBs and the regional monitoring supervision centers under MEP, plays the key role in enforcing the CFPPs compliance. Since 2010, MEP has usually released an annual notice on non-compliance with major air pollutants control regulations based on both on-site and CEMS data, disclosing the names of CFPPs and violation facts on its official website[43]. The majority of non-compliance enterprises have come from coal-fired power sector although companies from other energy industries and heavy industries are also reported. The reports contain information such as the profile of power units, in-operation rate of facilities, and overall pollutants removal efficiency. The removal efficiency usually ranges between 40% and 80%. The financial penalty be issued if CFPP units cannot meet the annual benchmark in-operation rate of pollution control facilities, which is 90%.

There are two significant compliance gaps. The first one is between pollutant removal efficiency in practice and the one in design. For example, the designed SO_2 removal efficiency should reach 90%, but in practice the rate only was 77.2% in 2012 as **Table 16** shows. The second one is between the practical in-operation rate and the benchmark rate of 90%. We assume that the annual monitoring penalty notice does not cover the whole story due to the nature of supervisory monitoring and lack of manpower and capacity compared to the size of CFPP fleets.

Figure 7: Provincial Organizational Structure in Air Pollution Prevention and Control



Source: Author's analysis, based on the information on the provincial EPBs.

[43] Announcement on the List of Abnormal Operation of Power Plant Desulphurization Facilities in 2010 and The Results of Penalty. MEP and NDRC, November 2011. Link: http://www.mep.gov.cn/gkml/hbb/bgg/201111/t20111122_220400.htm (in Chinese)

Although automatic supervisory monitoring system of pollution sources namely the CEMS data is usually similar among the EPBs, since the system has been developed and trained by the MEP, the way each Provincial EPB would work in supervising the CEMS data monitoring still has small differences. Using Henan Province as a case[44], the automatic supervisory system of CEMS data is monitored by data acquisition and transmission software on the front-end computer on site. The relevant parameters are monitored every 10 minutes, CEMS real-time data will be compared to the previous time monitored parameters, if the change is larger than the certain range preset by the EPB, all the real-time data of those parameters will be automatically uploaded at this point in time. When the back-end computer at the EPB Supervisory Center receives the parameters information, it will automatically compare the monitored data and the record data, and whenever inconsistencies are found, the alarm system will be triggered automatically. The three-level inspection system is as follows: first, the third-party operation and maintenance company would rule out the technical issues, then the abnormal information will go to the municipal level environmental supervision center for second review before the Henan Provincial Environmental Supervisory Center conducts the final review of the alarmed information.

5.1.The application of air pollution control devices (APCDs) in the Chinese Sector

According to the data from CEC, as of the end of 2015, the country has implemented flue gas desulfurization (FGD) in around 820 GW of power plants, accounting for 82.8% of thermal power capacity and 92.8% of the national coal-fired power capacity. By the end of 2015, of the thermal power plant fleet, flue gas denitrification unit capacity is 850 GW, accounting for 85.9% of the capacity of thermal power units, and 95.0% of the national coal power capacity[45].

To mitigate the severe impact of anthropogenic air pollutant emissions from power plants on human health and the environment, the Chinese government at the national, provincial and municipal levels have already implemented several control strategies over the past years to reduce PM, SO_2 and NO_X emissions. The penetration rates of abatement technologies between 1990 and 2010 can be seen in **Table 15.** It is clear from the table that starting in 2005, large, effective efforts were made to implement technologies, such as advanced low NOx burners (LNB) and FGD to reduce pollutants.

In regards to NO_x emissions, the use of traditional (LNB) increased during 1990-2005 and resulted in the about 1% of annual decrease of average NOx emissions per unit of power generation in the meantime[46]. Even though the penetration rate of advanced LNB jumped up from 7.4% in 2006 to 42% in 2010, the total NOx emissions still increased in 2006-2010 due to the higher coal consumption growth. By 2010, traditional LNB reached a penetration rate of 39.4% and advanced LNB reached a penetration rate of 42%.

44 Who will supervise the automatic monitoring of pollution sources? MEP Environmental Supervision Center. June 2016. Link: http://www.envsc.cn/details/index/1106 (in Chinese)

45 CEC releases thermal power plant environmental protection industry information for 2015. Link: http://huanzi.cec.org.cn/tuoliu/2016-04-25/152005.html (in Chinese)

46 Liu, F, et al. High-resolution inventory of technologies, activities, and emissions of coal-fired power plants in China from 1990 to 2010. Link: www.atmos-chem-phys.net/15/13299/2015/

Table 15: Penetration Rates of Air Pollutant Abatement Technologies

Technologies	1990	1995	2000	2005	2006	2007	2008	2009	2010
Traditional LNB	12%	22.1%	38.7%	53.7%	51.8%	46.6%	44.2%	42.1%	39.4%
Advanced LNB	0%	0%	0%	0%	7.4%	19.8%	29.2%	35.9%	42.0%
FGD	0.1%	1.0%	2.1%	12.2%	29.5%	49.9%	70.2%	81.9%	85.6%
Cyclones	7.6%	7.4%	5.2%	3.6%	3.0%	2.3%	1.6%	0.7%	0.3%
Wet Scrubbers	46.3%	40.4%	19%	6.9%	6.1%	5.0%	3.9%	3.1%	2.5%
ESP	44.3%	49.8%	72.5%	86.1%	87.5%	89.1%	90.8%	92.0%	92.8%
Bag Filters	1.7%	2.3%	3.3%	3.4%	3.4%	3.5%	3.7%	4.2%	4.4%

Adapted from: High-resolution inventory of technologies, activities, and emissions of coal-fired power plants in China from 1990 to 2010. Link: www.atmos-chem-phys.net/15/13299/2015 . Note: The penetration rate in the paper refers to the shares of coal consumption for each air pollution abatement technology.

Specifically, for different air pollutants, some details in terms of abatement technology deployment are described as follows:

- **PM**

Coal-fired power plants in China mainly use pulverized coal (PC) and circulating fluidized bed (CFB) boilers. In 2010,88% of CFPPs used PC boilers, and 12% used CFB boilers; for PC boiler units, 93% installed electrostatic precipitators (ESP), and 7% installed efficient bag filters; CFB boiler units are all using ESP approach to remove PM[47].

By the end of 2014, ESP, bag filters, and electric bag composite dust collectors installed were 77.3%, 9.0% and 13.7% of total CFPPs respectively; and the annual emissions of PM was about 0.98 million tons, down 38.8% over 2010 and 72.8% over 2005, PM emissions rate were 0.23 g/kWh, down 0.27 g/kWh over 2010 and 1.57 g/kWh compared to 2005[48].

- **SO_2**

The rapid reduction of SO_2 from CFPPs dates back to the *11thFYP* period (2006-2010), mainly through burning low sulfur coal and installing FGD equipment, both of which improved overall coal power plant performance. The ratio of FGD installation reached around 80%, covering nearly 600 GW installed capacity by the end of 2010, and reached a 91.4% installation rate for 760 GW by the end of 2014, (**Figure 8**).

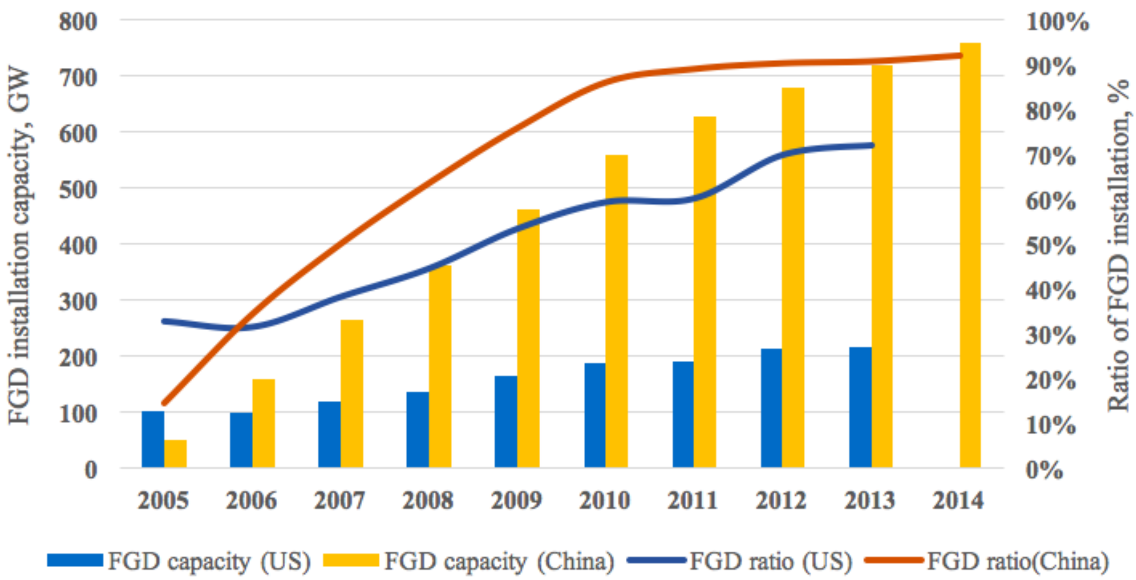
China continued to tighten the control of SO_2 emissions in the *12th FYP*, and FGD units have been further installed to CFPPs. By the end of 2015 almost all CFPPs were equipped with desulfurization units, and FGD installation rate was raised to over 95%, with the remaining percentage being

47 Hui M L *et al*. 2015. The mercury mass flow and emissions of coal-fired power plants in China. China Environmental Science. Vol 35(8)：2241~2250

48 Wang Z X *et al.* 'China's Electric Power Emission Reduction Policy Analysis and Outlook: China Electric Power Emissions Reduction Research 2015'. China Electric Power Press.

mainly the capacity with CFB boiler that having desulfurization function that without installing FGD.

Figure 8: Application of FGD in Chinese and American CFPPs



Adapted from 'China's Electric Power Emission Reduction Policy Analysis and Outlook: China Electric Power Emissions Reduction Research 2015' by Wang Z X et al., and Wang S X and Hao J M, 2012. Emissions of air pollutants from power plants in China.

- **NOx**

Currently, there are three major denitrification methods used in the Chinese Sector: low NOx burners (LNBs), selective catalytic reduction (SCR) and non-selective catalytic reduction (SNCR). Most new units have been installed with LNBs.

Since the request to install denitrification devices in coal-power plants by the Chinese government, NOx emissions have decreased since the *12th FYP*, and SCR has been popular due to its effectiveness and cost advantages[49]. In 2014, NOx from the thermal power sector was 6.2 million tons, down 25.7% over the previous year, accounting for about 30% of national total emissions; in 2014, per kilowatt-hour NOx emissions of thermal power generations was 1.47 grams, around 50% reduction compared to the 2010 level[44].

As of the end of 2014, China has put 687 GW of power plant flue gas denitrification into operation., accounting for 75.0% of the national thermal power unit capacity and 83.2% of the coal-fired unit capacity[50].

[49] Ma Z Z et al. 2016. Characteristics of NOx Emission from Chinese Coal-fired Power Plants Equipped with New Technologies. Atmospheric Environment. Vol 131: 164-170

[50] CEC released the thermal power plant in 2014 thermal industry information. Link: http://www.cec.org.cn/huanbao/jienenghbfenhui/fenhuidongtai/fenhuixinwen/2015-05-12/137681.html (in Chinese)

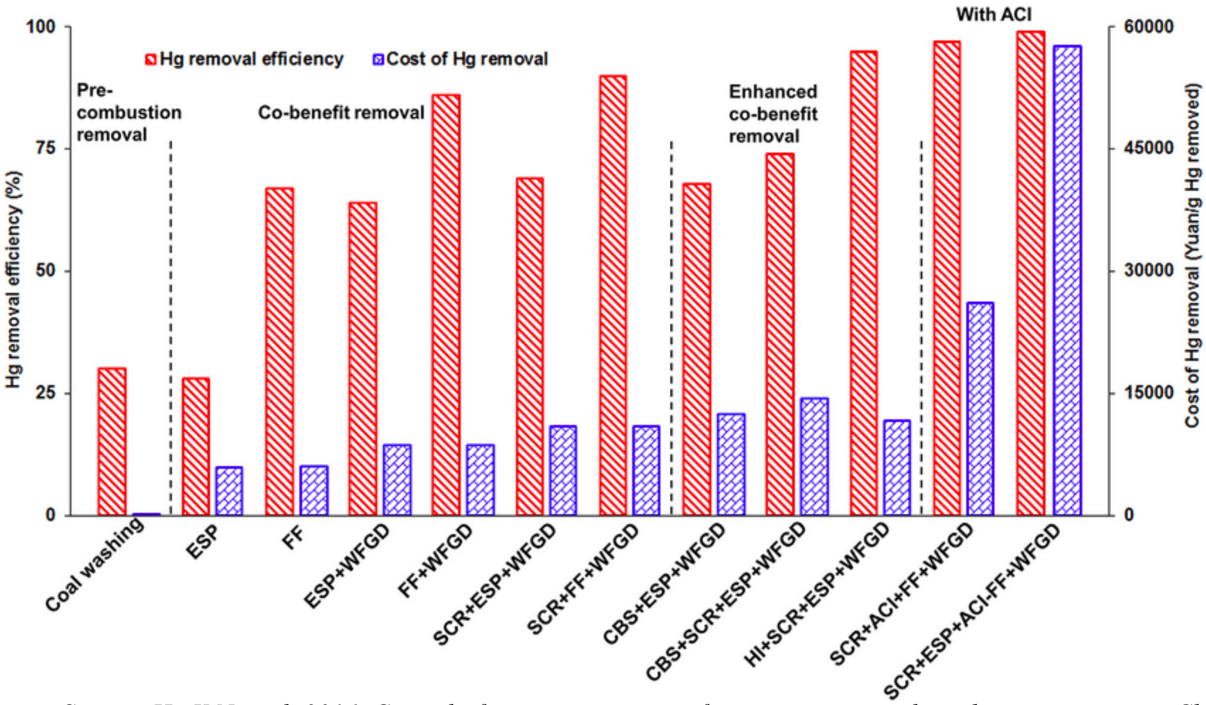
- **Mercury**

Current technologies such as coal washing, electrostatic precipitators, fabric filters, wet FGD, dry FGD, semi-dry FGD, and SCR, for PM, SO_2, and NO_x control can remove mercury[51]. The most cost effective technologies are fabric filter installation upstream of wet FGD.

The performance and costs of different mercury control technologies vary significantly. According to research done by China University of Geosciences, typical mercury removal efficiencies and annualized costs of mercury removal by coal washing and different combinations of air pollution control devices for CFPPs in China are shown in **Figure 9**.

Pre-combustion removal by coal washing is the lowest cost method of mercury removal, but the overall efficiency is relatively low, at under 30%. Fabric filters alone can achieve high mercury removal at a low cost, while the combination of SCR, FF and WFGD has higher cost-effectiveness compared to other combinations. The highest mercury removal efficiencies (95-99%) can be achieved through introducing mercury-specific control technologies such as ACI, but of course with elevated costs of removal.

Figure 9: Mercury Removal Efficiency and Cost of Removal



Source: Hu Y N et al. 2016. Control of mercury emissions from stationary coal combustion sources in China: Current status and recommendations. Environmental Pollution. Vol 218: 1209–1221
Note: Fabric filters (FFs), Wet flue gas desulfurization (WFGD), Activated carbon injection (ACI), CBS (coal blending and switching); HI (halogen injection)

5.2.The number of plants complying with applicable norms

[51] Controlling Mercury Emission for China's Coal Fired Electricity Plants: An Economic Analysis. Link: https://www.researchgate.net/publication/251712313_Controlling_Mercury_Emission_for_China%27s_Coal_Fired_Electricity_Plants_an_Economic_Analysis.

According to the CEC statistics, desulfurization equipment were installed on 91.6% of the existing coal-fired power capacity by the end of 2013, while denitrification equipment was only installed on around 50% of the units[52]. As required in the *12th FYP*, denitrification equipment was to achieve 100% installation by the end of 2015.

Because July 1st 2014 was the deadline for the existing CFPPs to implement the emission standards of PM, SO_2, NOx and mercury as specified in the latest Chinese *'Emission Standards of Air Pollutants for Thermal Power Plant' (GB13223-2011)*, during the three years' time prior to the effective date (2011-2014), the existing CFPPs were retrofitting to meet the emission standards, especially for the NOx and mercury.

Theoretically, all the CFPPs should comply with the *GB13223-2011* or local emission standard, depending on which standard is the more stringent. However, due to the technical reasons or poor enforcement, some plants fail in compliance with the standard.

Judging from the latest available disclosure information of the penalty notice from the MEP website[53], in 2014 there are in total 46 power plants from 17 power corporations whose desulfurization and denitrification facilities did not fulfill the requirements, and the main reasons for being on the list were exceeding emissions standards, unreliable CEMS data and malfunction of equipment. Of the 46 CFPPs, 37 plants failed to comply with the required NOx limit, and 21 plants failed in SO_2 compliance.

Considering the current existing CFPP number is close to 2,600, the rate of non-compliance is less than 2%; however, this is just an estimate since there are no figures for the year 2015 and 2016, and non-compliance being below the tolerance level might accumulate to the higher percentage since it would be possible that only the severe cases would be brought to the MEP level for publishing as penalty notice.

5.3.A summary of the overall success in reducing air pollution from the Chinese sector

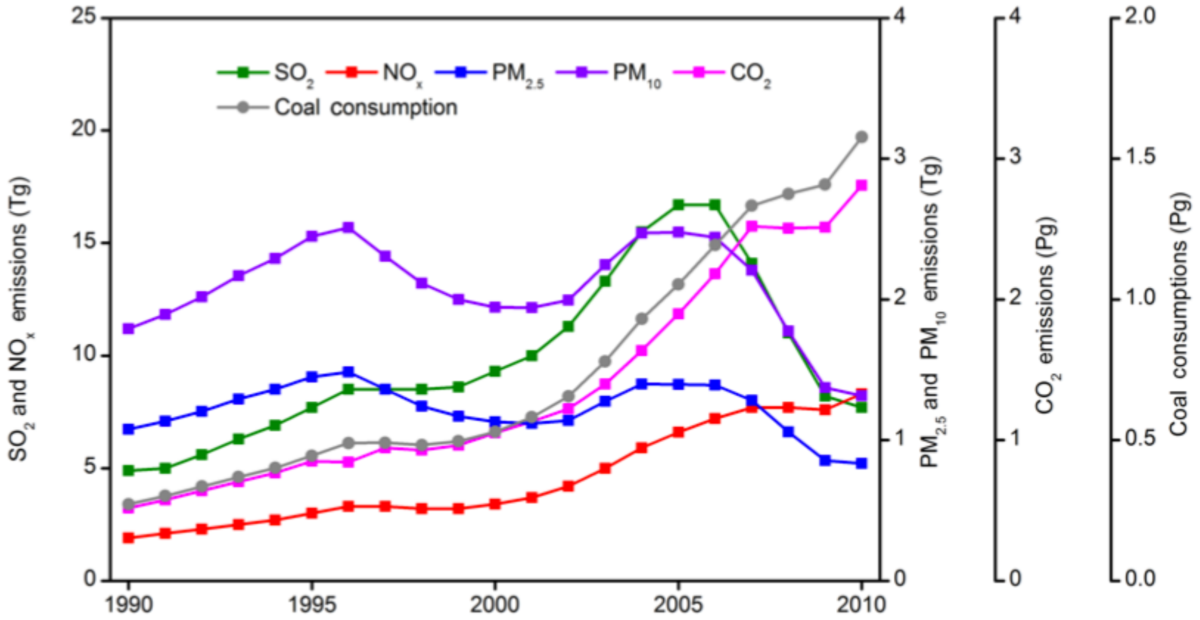
For reducing particulate matter, efforts have been underway for many years and have made significant progress since the mid-1990s. The measures taken were mainly successful in reducing PM and SO_2 emissions despite a growth in the coal industry, as FGD installation became a requirement in 2005. As shown in the **Figure 10**, SO_2 emissions peaked in 2006 at 16.7 million tons (Tg), and decreased by 54% from these levels by 2010, with an 84% FGD installation rate in coal plants by 2010. Additionally, PM emissions had two peaks in 1996 and 2005, due to changes in electricity demand and regulations. The first decline after 1996 is believed to be from slowdowns in the Chinese economy and implementation of the first amendment to the *'Emissions Standard of Air Pollutants for Thermal Power Plants (GB13223-1996)'*. The second decrease after 2005 was due to the stricter emission standards for thermal power plants (*GB13223-2003*), and they decreased by 40% ($PM_{2.5}$) and 47% (PM_{10}) between 2005 and 2010. Installation of FGD helped remove PM emissions, in addition ESP and bag filters with higher efficiency were installed due to new emission

[52] CEC announced the 2013 thermal power plant flue gas desulfurization, denitrification, dust industry information. Link: http://huanzi.cec.org.cn/dongtai/2014-05-07/121302.html (in Chinese)

[53] MEP's penalty notice on non-compliance of desulfurization and denitrification in 2014. Link: http://www.mep.gov.cn/gkml/hbb/bgg/201506/t20150625_304287.htm (in Chinese)

standards, and the remaining contribution should come from the phasing out small and inefficient generation units.

Figure 10: Coal Consumption and Air Pollutants Emissions from CFPPs in China (1990-2010)



Source: High-resolution inventory of technologies, activities, and emissions of coal-fired power plants in China from 1990 to 2010. Link: www.atmos-chem-phys.net/15/13299/2015/.

However, some challenges still remain to the technical implementation and reduction of pollutants. Although PM and SO_2 levels were reduced even with growth in the coal sector, CO_2 and NO_x emissions continue to rise with coal use. CO_2 emissions have no control measures, and although energy efficiency has improved leading to a reduction of CO_2 emissions per unit of energy by 20% from 1990 levels in 2010, they are still growing with coal use.

Due to the installation of pollutants control facilities, the environmental performances of CFPPs fleet have improved in the recent years. **Table 16** shows the annual installation of pollutants removal facilities installation in the thermal power plants from 2010 to 2012. According to the *'Coal-Fired Generating Units Desulfurization Electricity Price and Desulfurization Facilities Operation and Management Approach (Interim)'* released in 2007 [54], the CFPP desulfurization efficiency[55] should generally reach more than 90% in order to ensure that the sulfur dioxide emissions standards, but the southwestern region due to its high sulfur coal consumption, the desulfurization efficiency to be 95%, in northwestern and northeastern low sulfur coal area the efficiency should reach 80% to meet the emission standard. Based on the figures of desulphurization efficiency, the average percentage had been increasing from 2010 to 2012, but the efficiency level still could not meet the requirement in the *Operation and Management Approach*; the denitrification efficiency was apparently lagging behind desulphurization, and reached 10.2% in 2012 due to the later commencement of NOx emissions regulative policies. This observation

---

[54] Coal-Fired Generating Units Desulfurization Electricity Price and Desulfurization Facilities Operation and Management Approach (Interim). MEP and NDRC 2007. Link: http://www.zhb.gov.cn/gkml/hbb/gwy/200910/t20091030_180711.htm (in Chinese)

[55] Desulfurization efficiency or removal efficiency refers to ratio of SO_2 quantity in the flue gas removed after desulfurization to the SO_2 quantity before getting through the desulfurization facilities; and in China it may refer to the efficiency at the facility level, and sometimes at the sectoral level, depending on the circumstances.

implied that although the penetration rate of desulphurization and denitrification is getting higher, the removal efficiency has not been satisfying, the reasons behind this discrepancy were complicated, owing mainly to the limited number of installed units, inadequate in-operation rate[56] of the desulphurization and denitrification equipments, and the loose enforcement of the relevant environmental regulations. In recent years, due to the tightened emission standards, the extensive application of CEMS, and the supervisory monitoring platform from the local EPBs getting more and more mature, the desulphurization and denitrification efficiency should be improved substantially, while due to the lack of statistical evidence, this is just our speculation.

Table 16: The Annual Installation of Pollutants Removal Facilities in Thermal Power Plants

Year	Desulfurization		Denitrification	
	Installed units number	Removal efficiency	Installed units number	Removal efficiency
2010	3,266	69.5%	N.A.	N.A.
2011	3,379	74.5%	274	6.5%
2012	3,465	77.2%	438	10.2%

Source: Zhu L et al. The Medium and Long Term Strategy Research for Air Pollution Control and Environmental Protection in China Coal-Fired Power Sector. China Electric Power Press (in Chinese). Note: Here the removal refers to the pollutants removed at the sectoral level.

The **Table 17** shows the emission reduction trend of Chinese thermal power plants during 2013 to 2015. As CFPPs capacity account for over 95% of national thermal power capacity until 2015 [57], the numbers in the table can largely tell the similar story for the major pollutants emission from CFPPs. The recent trend is clear that the total emission quantities and the share to national total emissions of SO_2, NOx and PM are both decreasing, especially for the NOx during 2013 to 2015.

Table 17: Major Pollutants Emission from Chinese Thermal Power Plants (2012-2015)

(million tons)	SO_2	Share of national total	NOx	Share of national total	PM	Share of national total
2012	8.53	40.3%	9.48	40.6%	1.51	12.2%
2013	7.83	38.3%	9.65	43.3%	2.19	17.1%
2014	6.83	34.6%	7.83	37.7%	2.36	13.6%
2015	5.28	28.4%	5.52	29.8%	1.65	10.7%

Source: Consolidated data from China Environmental Statistics Bulletin. MEP. Link: http://www.zhb.gov.cn/gzfw_13107/hjtj/hjtjnb (in Chinese). Note: Data for thermal power plants is used here, since there is no data on CFPPs on the MEP bulletins,

[56] In-operation rate refers to the ratio of the annual operating time of the desulphurization facility to the annual operating time of the coal-fired generating set.

[57] CEC China Electricity Statistics 2011-2015 on CEC website. Link: http://english.cec.org.cn/

Other compliance measures

The achievements have been a combination of policy measures, not only through tightening the emission standards and enforcing the FGD installation, but also other measures such as the small plant closure program and promotion of ultra-low emissions CFPPs.

6. The Status of Implementation of Continuous Emissions Monitoring Systems (CEMS)

Continuous Emissions Monitoring Systems (CEMS) were introduced to China in the 1980s, not until the early 2000swere they given more attention due to the requirement of better environmental governance from the environmental authorities, and release of several regulations in automatic pollution sources monitoring has stimulated their quick development.

6.1.Regulatory background on the implementation of CEMS for CFPPs

The mandated installation of CEMS for CFPPs' air pollutant and waste water discharge are required by laws, but so far there is no specific requirement of monitoring the ambient air quality of CFPPs.

- CEMS for air pollutants emissions from CFPPs

The overarching law on CEMS for CFPP air pollutants is the *'Law on Air Pollution Prevention and Control'* (2015), and its Article 24 stipulates that 'The key pollutant discharge entities shall install the automatic monitoring equipment for air pollutant discharge, network with the monitoring equipment of the environmental protection department and ensure the normal operation of the monitoring equipment and public information disclosure. …. The list of key pollutant discharge entities shall be decided by the environmental protection departments, according to key pollutant discharge control targets and the types, quantity and concentration of pollutants discharged according to the environmental capacity of the administrative area.'

There are several regulations and guidelines to implement the requirements for the CEMS, but the most important one is the *'Measures for the Automatic Monitoring and Management of Pollution Sources'*[58], which sets detailed requirements for implementing CEMS. To enforce the requirement for environmental monitoring, the MEP also released the *'Administrative Measures for Environmental Monitoring'*[59], setting monitoring protocols for environmental departments exercising supervisory monitoring to the stationery pollution sources such as CFPPs, and for the ambient air quality monitoring and emergent environmental damage monitoring.

'Specification for Environmental Monitoring of Thermal Power Plant' (DL/T414-2012) from the NEA set the guidelines for conducting environmental monitoring for thermal power plants. Additionally, there is a new national level *'Self-monitoring Guidelines for Pollution Sources in*

[58] Measures for the Automatic Monitoring and Management of Pollution Sources, MEP Order NO. 28. Link: http://www.mep.gov.cn/gkml/zj/jl/200910/t20091022_171832.htm (in Chinese)

[59] Administrative Measures for Environmental Monitoring, MEP Order NO. 39. Link: http://www.zhb.gov.cn/gkml/zj/jl/200910/t20091022_171846.htm (in Chinese)

Power Plant' to be released soon[60], which just finished public consultation and is to be released soon in 2017. These two technical guidelines will cover both air pollutants and wastewater discharge.

- CEMS for wastewater discharge from CFPPs

The overarching law for deploying the CEMS is the *'Law on Water Pollution Prevention and Control'* (2008)[61], and its Article 23 stipulates that 'The key pollutant discharge entities shall install automatic monitoring equipment for water pollutant discharge, provide networks with the monitoring equipment of the environmental protection department, and ensure the normal operation of the monitoring equipment. Enterprises discharging industrial waste water shall monitor the industrial wastewater discharged and keep the original monitoring records'. The Law also asked the environmental protection departments to compile a key pollutant discharge entities list.

Specific measures had been formulated by the environmental protection departments, most of which are the same as described in the CEMS for air pollutants part.

6.2.The application of CEMS in the Chinese Sector

The 1996 *'Emission Standards of Air Pollutants for Thermal Power Plants', GB13223-1996,* firstly suggested that thermal power plants install CEMS. By 2004 around 400 CEMS had been installed in 180 coal power plants, but due to relatively poor environmental regulation and enforcement at the time, only 20% of the CEMS at the time were functioning normally, and many local environmental protection bureaus did not accept data from CEMS. Since then the CEMS installation increased, and the revision of *the GB13223* in 2011 as well as the *'Measures for the Automatic Monitoring and Management of Pollution Sources'* released in 2005 reinforced the compliance of installing CEMS for both air pollution and wastewater. By 2010, data from CEMS was accepted by local bureaus, although with some distrust of data reliability[62]. Now almost all CFPPs are equipped with the CEMS for air pollutants and waste water and all the real-time data are connected to the monitoring network managed by the environmental monitoring departments under local EPBs and MEP.

The system of establishing the *'List of Key Pollutant Discharge Entities'*[63] required by the *'Laws on Pollution Prevention and Control'* set the legal background of mandating the installation of CEMS for both air pollutants and wastewater, since almost all the CFPPs are on that list.

---

[60] Self-monitoring Guidelines for Pollution Sources in Power Plant. MEP 2016. Link: http://www.mep.gov.cn/gkml/hbb/bgth/201607/t20160719_360950.htm(in Chinese)

[61] 'Law on Water Pollution Prevention and Control'. President Order 2008. Link:http://www.gov.cn/flfg/2008-02/28/content_905050.htm (in Chinese)

[62] Improvements in the Operation of SO_2 Scrubbers in China's Coal Power Plants. Link: http://pubs.acs.org/doi/abs/10.1021/es1025678

[63] List of Key Pollutant Discharge Entities for 2016. MEP January 4th, 2016. Link: http://www.zhb.gov.cn/gkml/hbb/bgt/201602/t20160204_329897.htm (in Chinese)

6.3. Major challenges encountered by the Chinese sector in deploying CEMS

Coal-fired power plants can basically run CEMS to comply with the relevant provisions, but there are some problems. A survey concerning CEMS conducted by CEC and several power corporations shows that the main problems in the process of operation and maintenance of coal-fired power plants are failure of monitoring instruments, insufficient levels of operation and maintenance personnel, slow response of third party operation and maintenance, and large capital pressure[64]. CEMS component replacement is the main expenditure of operation and maintenance. The survey also shows that 99% of the power plants meet the 7-day technical specification requirement. There are about 71.2% of the surveyed plants using third party operation and maintenance, and among these plants about 27.7% reflect that the response of third party is slow.

In addition, the error limits of existing CEMS measurement technologies for coal-fired power plants, especially for low concentrations of PM, make it difficult to support the detection and monitoring of flue gas emissions under 'Special Emission Limits' and 'Ultra-Low Emissions'. The measurement methods of CEMS of coal-fired power plants are mainly the light scattering method (about 79.3%) and turbidity method (about 19.4%), and the measurement error mainly comes from the direct measurement error of the dust instrument, the indirect error caused by the manual calibration, irregular instrument calibration, and drift error caused by the span. Reference methods used by the manual sampling weight method are based on a sampling analysis of particulate emission concentrations greater than 20 g/m^3, as when the concentration is less than 20 g/m^3, the error of manual measurement is relatively large. In the requirements from '*Specifications for CEMS of Flue Gas Emitted from Stationary Sources'* (*HJ/T 75-2007)*[65], the reference methods of technical assessment state that when the particulate emission concentration ≤50 mg/m^3, the absolute error does not exceed ±15 mg / m^3. Method error limits cannot meet the Special Emission Limit of 20 mg/m^3requirements in *GB 13223-2011*, and lower emission limits requirements (10 mg/m^3 or 5 mg/m^3). Whether the CEMS monitoring data can truly reflect lower emission concentrations requires more scientific proof.

Some other main problems of CEMS in coal fired power plants are as follows. In the aspect of regulations and policies, it is urgent to carry out relevant research and timely revisions to the two technical guidelines of *HJ/T 75-2007* and *HJ/T 76-2007 (Specifications and Test Procedures for CEMS of Flue Gas Emitted from Stationary Sources)*[66] to adapt to the new requirements of pollution control and monitoring. In practice, the relevant policies about CEMS have discrepancies, showing problems such as duplication, overlapping and inconsistency among these regulations. In terms of CEMS technology, Chinese technology is not inferior to that of foreign countries, but there are still gaps in the details of the technology deployment compared with the advanced international levels. In addition, because coal-fired units are influenced by the operating conditions, load scheduling, coal quality changes and other factors, the stability and accuracy of CEMS also have an impact.

---

[64] Wang ZX *et al.* Current Situation Analysis on CEMS of Coal-fired Power Plants in China. 2014. By China Electric Power Press

[65] Specifications for CEMS of Flue Gas Emitted from Stationary Sources. MEP 2007. Link: http://kjs.mep.gov.cn/hjbhbz/bzwb/dqhjbh/jcgfffbz/200707/t20070716_106784.htm (in Chinese)

[66] Specifications and Test Procedures for CEMS of Flue Gas Emitted from Stationary Sources. MEP 2007. Link: http://kjs.mep.gov.cn/hjbhbz/bzwb/dqhjbh/jcgfffbz/200707/t20070716_106786.htm (in Chinese)

- Concerns from EPBs of using CEMS data for enforcement

In terms of using CEMS data as the legal evidence for non-compliance of the CFPPs and other polluters, MEP and the local EPBs are facing the challenge of whether employing the CEMS data only as clues for conducting enforcement investigations or if it could be used as legal evidence for issuing penalties; the current practice is the former, namely after sensing the abnormal data from the CEMS, on-site investigation will be conducted for evidence collection before the final decision to be made for judging as non-compliance.

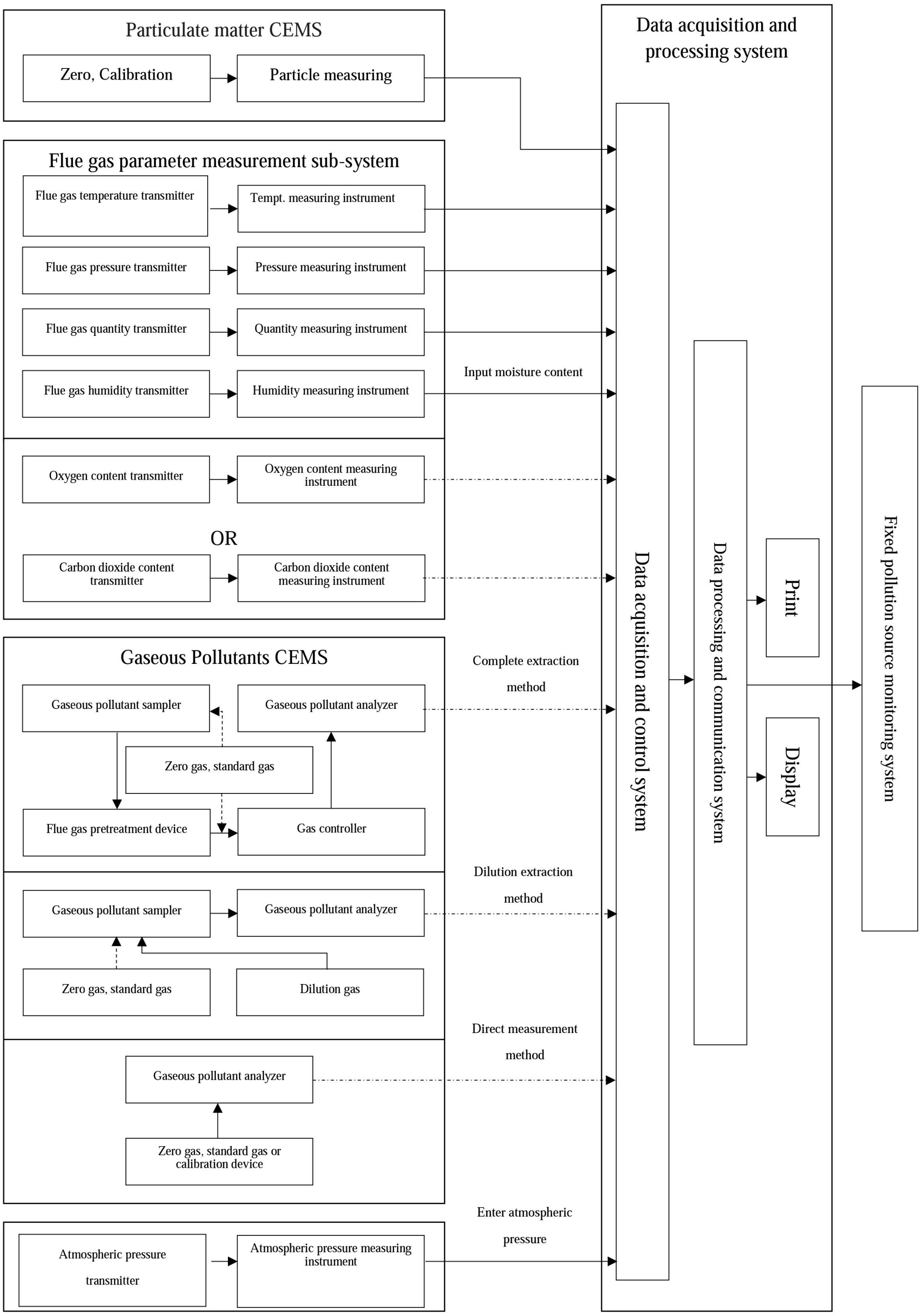
EPBs still have concerns of using the CEMS data as direct evidence to impose penalties, since this will lead to the situation that enforcement divisions under the EPB and the polluters will surely have conflicts on arguing the validity of the supervisory monitoring system, and this will bring tremendous pressure to the environmental supervision agencies under the EPBs. The internal pressure would be if the penalty could not be promptly issued after spotting the non-compliance behaviour, the EPB's related division may be held accountable for administrative misconduct; the external pressure would come from the potential legal issues if the polluter insists that the penalty is unreliable of only using the CEMS data and sues the EPB to the court.

6.4.CEMS system for environmental compliance

The Chinese governmental departments introduced more than sixty monitoring standards, technical specifications and equipment technical standards for CEMS, and made provisions for CEMS data collection, processing and reporting. By December 31st 2015, there were more than 50 qualified Chinese CEMS certification manufacturers, and more than 60 types of qualified product models[67]
CEMS of flue gas from stationary pollution sources consists of particulate matter CEMS and/or gaseous pollutants CEMS (including O_2 or CO_2) and a flue gas parameter determination subsystem. The system must monitor flue gas temperature, flue gas pressure, flow speed or flow quantity, the water content of flue gas (or the moisture content of input gas), and the oxygen content of flue gas (or the carbon dioxide content) via sampling or non-sampling methods; calculate the emission rate and emission quantity of flue gas pollutants; and display and print parameters, charts and transfer data through transmission system to the management departments. The typical system structure diagram recommended for the Chinese Sector is shown in the following graph.

[67] Flue gas CEMS certification testing qualified manufacturers directory. Link: http://www.cnemc.cn/publish/113/news/news_46989.html (in Chinese)

Figure 11: Illustration of CEMS System Composition



Source: Adapted from the graph in 'Specifications and Test Procedures for Continuous Emission Monitoring Systems of Flue Gas Emitted from Stationary Sources' (HJ/T 75-2007)[68]

[68] Specifications for Continuous Emissions Monitoring of Flue Gas Emitted from Stationary Sources (HJ/T 75-2007) , Link: http:// english.mep.gov.cn/standards_reports/standards/Air_Environment/air_method/200809/t20080922_129147.htm

The maintenance of CEMS should follow the requirements in the *HJ/T 75-2007*, which specifies the exhaust parameters and the main technical indicators of CEMS, namely testing items, installation location, commissioning and testing methods, acceptance methods, daily operation and management, daily operation quality assurance, data review and reporting data format.

Data collection, reporting, and communication protocol should conform with the requirements in the *'Standard for Data Communication of Pollution Emission Auto Monitoring System' (HJ/T212-2005)*[69], to standardize data transmission and ensure the connectivity among all kinds of CEMS equipment, transmission network and environmental protection department application software system. This *Standard* also specifies the CEMS monitoring center and automatic monitoring equipment between the data communication, control and alarm information transmission protocol.

CFPPs will be facing technical issues in fulfilling the required specifications, especially for the CFPPs with newly equipped CEMS, necessary maintenance and routine check are needed. The common failure phenomena in operating CEMS are listed in the following table:

Table 18: Common Failures with the CEMS in China

Sub-system of CEMS	Failure Phenomena
Cabinet	• The measured value is incorrect: SO_2, NO value low or O_2 value high • The data shown on analyzer does not correspond to the IPC or DCS • The data measured by analyzer has deviation
Suction probe	• Cannot heat up • The filter is clogged • The probe is clogged • The air switch trips • Leakage
PM Measuring instrument	• The measured value is high • The measured value is low • The value shown on PM measuring instrument does not match the DCS • Show no valid signal
Pitot tube flow rate measuring instrument	• The measured value is incorrect • Fluctuations in flow rate • The measurement indication is zero or the transmitter has no output
Pressure Transmitters	• The measured value is incorrect
Temperature Transmitter	• The measured value is incorrect

Source: Adapted from 'China's Electric Power Emission Reduction Policy Analysis and Outlook: China Electric Power Emissions Reduction Research 2015' by Wang Z X et al.

[69] Standard for Data Communication of Pollution Emission Auto Monitoring System' (HJ/T212-2005), Link: http://www.ptepb.gov.cn/zwgk/fgwj/bmwj/20140213/100900051.shtml (in Chinese)

6.5.Role of CEMS in improving environmental compliance and governance

While China's 300MW/600MW thermal power unit technology introduction project started for the first time in 1981, China first introduced four sets of CEMS from abroad, but also cultivated a number of technical backbones of CEMS application and development, not only to promote the domestic CEMS work, but also to lay the foundation for development of China’s CEMS Manufacturing industry.

The1996-issued the *Emission Standard of Air Pollutants for Thermal Power Plants* for the first time required new, expanded, renovated thermal power plants to install CEMS. In 2001, MEP issued the *‘Technical Norm for Continuous Emission Monitoring of Flue Gas Emitted from Thermal Power Plants’*, which was replaced by the *‘Specifications for Continuous Emissions Monitoring of Flue Gas Emitted from Stationary Sources’ in* 2007, and the *‘Specification and Test Procedures for Continuous Emission Monitoring Systems of Flue Gas Emitted from Stationary Sources’*, which was replaced by a requirement by the same name in 2007. The continuous monitoring of flue gas emissions in China started to become regular.

With environmental awareness in China increasing rapidly in recent years, the government has made great efforts to reduce energy consumption and protect the environment. China's environmental protection has developed rapidly, its scale is very large, and emission standards are becoming increasingly stringent.

In 2014, the NDRC and the MEP jointly promulgated the *‘Measures for the Supervision and Management of Environmental Protection Electricity Prices and Environmental Protection Facilities for Coal-fired Generating Units*[70]*’*, which strictly controls the discharge of coal-fired power plants. It plays an important role in improving air quality. The *Measures* strengthening the supervision of environmental protection facilities require on-line monitoring of the operation of environmental protection facilities and monitoring of on-line monitoring data; require CEMS to have two channels to verify the authenticity of data; require coal-fired power plants to join the Corporate Power Generation Main Equipment Management System for unified management; and require punishment of fraudulent CEMS and DCS (Distributional Control System) data.

6.6.Initiatives to further improve CEMS in the Chinese sector

The current initiatives of improving CEMS focus on the improvement of the data quality, management capacity and technical issues among others. To further improve the data quality of automatic monitoring data and strengthen the effective supervision of key polluting sources, the environmental authorities have been promoting automatic monitoring equipment, dynamic management and control systems, and have selected several provinces to choose pilot enterprises to install this system.

The ‘*Self-monitoring Guidelines for Pollution Sources in Power Plant*’ mentioned above will be the main technical guidelines for implementing CEMS and one intention of this *Guidelin*e is to ensure the compliance of self-monitoring to get more reliable data, which can then be used for the pollution discharge permit trading and environmental law enforcement.

[70]Measures for the Supervision and Management of Environmental Protection Electricity Prices and Environmental Protection Facilities for Coal-fired Generating Units. Link: http://www.sdpc.gov.cn/fzgggz/jggl/zcfg/201404/t20140403_615508.html (in Chinese)

The Bureau of Environmental Supervision under the MEP is in charge of the CEMS related issues and has established the Environmental Supervision Center to provide technical supports to the provincial EPBs on CEMS installation and operation at the State Key Pollutant Discharge Entities (all CFPPs are on the list). Specifically, since 2010 the Center has organised several training workshops to enhance the capacity of the local EPBs in terms of better using the CEMS in environmental supervision and exchanging experiences among the peer EPBs (**Table 19**).

Table 19: Capacity Building Workshops Done by the Environmental Supervision Center

Year	Training Contents
2010	CEMS data automatic supervision for State Key Pollutant Discharge Entities
	Levy on the pollution charges for state key pollutant discharge entities
2011	2011 Series of Training in Zhengzhou: Automatic supervision of CEMS data and environmental supervision enforcement
	2011 Series of Training in Changchun: Automatic supervision of CEMS data with pollution charge and on-site inspection
	2011 Series of Training in Haikou: Automatic supervision system operation and CEMS data quality control
2013	CEMS data communication effectiveness and CEMS supervisory software upgrading (3 sessions in 2013 at different locations)
2014	Common issues with automatic supervision of CEMS data and how to conduct on-site inspection
	Investigation on the situation of CEMS data manipulation in Shandong Province: Experience sharing event
	On-site field data collection and report at the controlled pollution sources
	On-site inspection of the CEMS system in Xingcheng, Liaoning Province

Source: Compiled by REEI, based on the information on the website of MEP Environmental Supervision Center, Link: http://www.envsc.cn/download/ (in Chinese)

7. Major Challenges Encountered by The Chinese Sector in Compliance for Air Pollution and Energy Efficiency

To comply with the standards related to air pollution and energy efficiency, there are both technical and financial challenges recognized as follows:

7.1.Major technical and financial hurdles

- Barriers from the power grid management: peak load regulating

Due to China's high-efficiency coal-fired units' large capacity and low utilization hours and frequent involvement in peak shaving, it is difficult for the ultra-supercritical units to run in the best working conditions, and therefore an energy efficiency advantage is difficult to achieve, leading to a certain extent of increasing air pollutants emissions.

- Challenge to the monitoring devices

The current air pollutant emission standards for thermal power plants in China (see **Table 5**) are among the world's most stringent ones. The ultra-low PM emission limit of 10 mg/m^3, for example, has put forward a challenge to the monitoring devices since this low level falls in the detection error range of some instruments, and therefore many power plants have insufficient monitoring equipment or face problems with accuracy of their testing results.

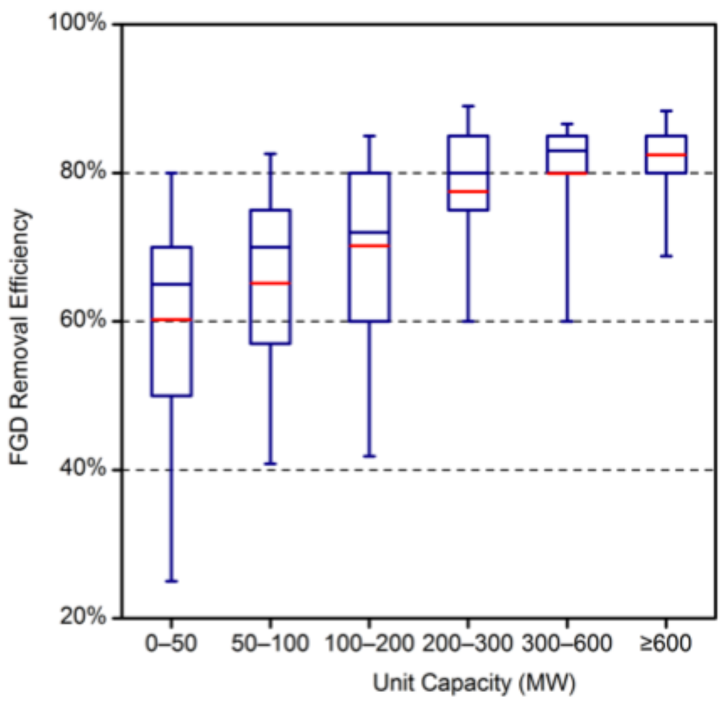
- Different statistical method

Regarding the statistical data to be used in environmental statistics, there are different statistical methods and varied calculation methods. Some power plants use real-time monitoring data through on-line monitoring systems, while others use material balance or emission factor methods to estimate the emissions data. The difference makes it difficult to reflect the actual emission levels of power plants.

- Removal efficiency of pollutants

A challenge of compliance is the efficiency of pollutant removal, as can be seen in **Figure 12**, pollutant removal efficiency drastically increases with larger capacity plants for FGD. This is a technical challenge that will need to be addressed as large units contributed only to a bit more than half of total SO_2 emissions in 2010 although making up more than 75% of total capacity[71]. The relatively low removal efficiency level of the smaller units need to enhanced.

Figure 12: FGD Removal Efficiency among Different Unit Capacity Size



Source: High-resolution inventory of technologies, activities, and emissions of coal-fired power plants in China from 1990 to 2010. Link: www.atmos-chem-phys.net/15/13299/2015/.

- Trade-offs between investment cost and subsidies

[71] High-resolution inventory of technologies, activities, and emissions of coal-fired power plants in China from 1990 to 2010. Link: www.atmos-chem-phys.net/15/13299/2015/

The technical adoption of pollutant controlling mechanisms in coal fired power plants has proven to be a challenge as well as an opportunity for the coal sector to comply with air pollution standards. The CFPP owners' investment and operation costs in air pollution control devices will be mainly subsidized by electricity premium, which is a preferential tariff for the CFPPs with eligible desulfurization, denitrification and de-dusting equipment installed and in operation (for details on the premium tariff, please refer to **Section 8.2**). Therefore, the CFPP owners consider the trade-offs between investment cost and the offered tariff subsidies as one important factor in deciding the CFPP's air pollutants removal performance, especially removal efficiency and operation time, which could lead to the possible misconduct of the CFPP for lower removal efficiency and insufficient operation hours since the supervisory monitoring from the EPBs were relatively poor when the CEMS was not in place or at the early stage of development. Although any CFPPs can receive all premiums if they install and operate all three pollutant control technologies, of course on condition of complying with the required emission standards, in practice there were still CFPP owners would like to get all the subsidy without adequate time of running the APCDs or having cheats on the CEMS, which has become one of the focuses of the EPBs to deal with in the past several years.

7.2.The constraints in the supply of pollution control equipment

China has implemented a progressive pollution control strategy of reducing the pollutants emissions of thermal power plants. The reduction of SO_2 emissions was prioritized in the *11th FYP* (2006-2010) and NOx became the focus of the *12th FYP* (2011-2015). PM was the secondary target in the process. In the updated *GB13223-2011*, mercury was listed in the pollutant control category. By the end of 2015, most of China's CFPPs have been equipped with desulfurization and denitrification facilities. The technology and equipment costs decline fast thanks to the increasing market demand. Meantime the domestic equipment suppliers gain the market share while foreign suppliers still hold some technology advantages, such as mercury emission control technology[72]. The government regulation and premium scheme play a big part in installing desulfurization and denitrification facilities in CFPPs. However, to save the operation and maintenance costs, many plants do not put the facilities into full-time operation, which has remained as a big challenge towards the implementation of pollution control of CFPPs.

The push for installing air pollution control devices for CFPPs has mainly depended on the requirements of environmental laws and regulations from the government, rather than from the corporate environmental awareness. For CFPPs, desulfurization and denitrification facilities would require a large one-time investment cost and later-on continuous operation costs, without distinct corresponding returns on investment, as the benefits are mainly environmental and social benefits, and some economic benefits only when certain operation hours could be guaranteed. Therefore, if there are no mandatory requirements of the regulations on reducing pollutants to certain levels or the penalty of non-compliance is not high enough, the CFPPs will not have the motivation to install the abatement facilities. It is vital that the enforcement of the environmental standards should be strong before a satisfactory adoption rate is seen.

---

[72] The preparation instructions for '*Emission Standards of Air Pollutants for Thermal Power Plant'* (Second consultation draft), MEP 2011. Link: http://www.zhb.gov.cn/gkml/hbb/bgth/201101/W020110120352208669465.pdf (in Chinese)

As mentioned, another major factor restricting the deployment of pollution control equipment deployment is electricity pricing, without the introduction of a number of supporting financial policies such as a premium tariff, power corporations will see the retrofitting as a heavy financial burden.

7.3.Actual time taken to install pollution control technology

The new emission standards *GB13223-2011*came into effect on January 1st 2012. Regarding the compliance timeframe, there are different regulatory requirements for varied thermal power plants. Since July 1st 2014, the existing coal-fired power boilers to implemented the new emission standards of PM, SO_2 and NOx; since January 1st 2012, the new coal-fired power generation boiler to implemented the emission standards of PM, SO_2 and NOx; since January 1st 2015, coal-fired boilers implemented the mercury emission limits specified in the standard.

The MEP released the inventory of desulfurization and denitrification facilities in 2014 [73], and all the CFPPs fleets are on the list with enterprise name, operation year, installed capacity, technology employed, APCD operation year and the companies who install and run the APCDs.

The actual time taken to install the pollution abatement equipment depends on the decisions from the power corporation management level, the mode of operation for the equipment, engineering design of the pollution control system and the choice of suppliers through tending process or equipment procurement if using the in-house engineering team. In terms of the key players in installing and operation the APCDs, CEC released ranking of the companies specializing in CFPP desulfurization, denitrification and PM removal Beijing Guodian Longyuan Environmental Engineering Company ranked top on the accumulated installed capacity of new desulfurization facilities, by the end of 2015, the company had completed the total project installed capacity of circa 101 GW[74]. According to the completed desulfurization and denitrification project list on the company's website, the name of the CFPPs, installed capacity and project construction time were all given for their projects before the end of 2012. According to all the 103 desulfurization and denitrification projects done by Beijing Guodian Longyuan Environmental Engineering Company during 2009 to 2012, **Table 20** gives a range of how long will it take for different size of generation units. However, the information in the table is just for a reference and might not reflect the actual time taken, since many factors will affect the time such as operation of the CFPP, space availability, power system complexity and so on.

[73] National coal-fired unit desulfurization and denitrification facilities and other key air pollution reduction projects inventory. MEP 2014. Link: http://www.zhb.gov.cn/gkml/hbb/bgg/201407/t20140711_278584.htm (in Chinese)

[74] CEC announced the 2015 thermal power plant environmental protection industry information. Link: http://huanzi.cec.org.cn/tuoliu/2016-04-25/152005.html (in Chinese)

Table 20: Construction Time for Desulfurization and Denitrification Facilities by A Major Environmental Engineering Company

(Months)	Desulfurization	Denitrification
150-199 MW	8.0	N.A.
200-299 MW	12.5	N.A.
300-400 MW	20.0	16.0
600-700 MW	25.7	13.7
1000 MW	23.3	17.2

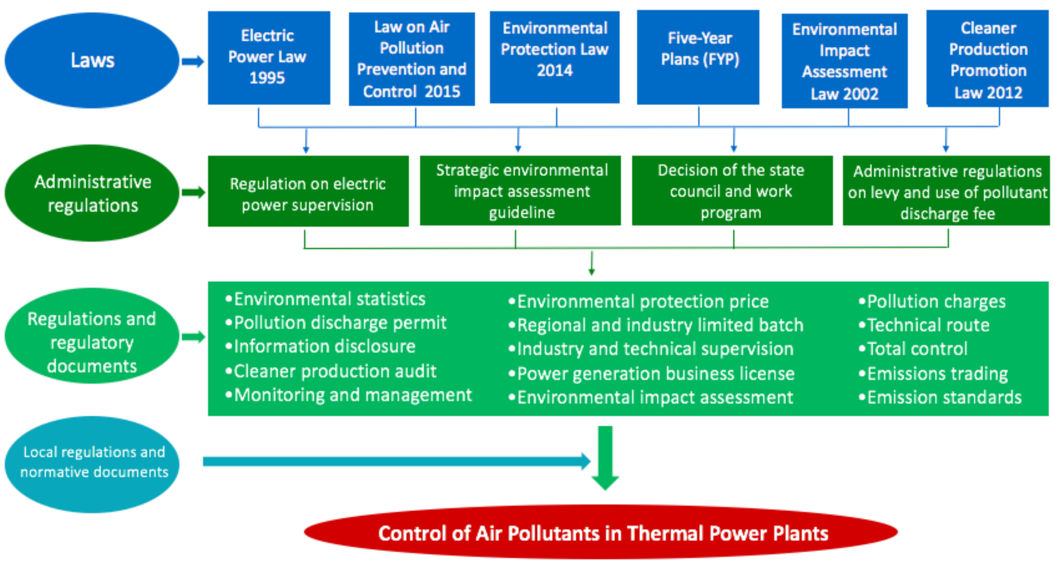
Source: Author's own compilation and calculation, based on the desulphurization projects list and denitrification projects list on the website of Beijing Guodian Longyuan Environmental Engineering Company. Link: http://www.lyhb.cn/yjxm (in Chinese). Note: All projects since 2009 to 2012, excluding the retrofitting projects

8. Policy Support to the Chinese Sector in Compliance of the Air Pollutants Emission Standards

The latest '*Law on Air Pollution Prevention and Control*' was formally effective from January 1st, 2016, specifically regarding coal power, the following article is listed in the *Law's Article 41: 'Coal-fired power plants and other coal-burning units shall adopt cleaner production techniques, supporting the construction of dust removal, desulfurization and denitrification facilities or other measures to control air pollutant emissions.*' This regulation has laid the legal foundation of the Chinese Sector to comply with the emission standards mentioned in the previous sections.

At the implementation level of the *'Law on Air Pollution Prevention and Control'*, a range of policy measures have been released in the past several years to help the Chinese Sector to comply with the stringent emission standards, ranging from technical assistance, financial support and penalty measures. Also, other legal regulations have been playing an important supportive role in achieving the goal of meeting environmental standards and reducing air pollution (**Figure 13**).

Figure 13: Regulatory Framework of Air Pollution Control in China



Source: Author's own analysis

8.1. Technical assistance

The MEP released several technical guides in 2005 to promote the deployment of dedusting, desulfurization and denitrification equipment, covering the major technologies on the market. These guidance documents give the specifications on planning, design, review, procurement, construction and installation, commissioning, inspection and operation management of the pollutants abatement equipment.

Table 21: Technical Specifications in Air Pollutants Control for Thermal Power Plants

Pollutants	Technical Specifications
SO_2	*Flue Gas Circulation Fluidized Bed Desulfurization Project Technical Specification of Thermal Power Plant (HJ/T 178-2005)*
	Flue Gas Limestone/Limegypsum Desulfurization Project Technical Specification of Thermal Power Plant (HJ/T 179-2005),
	Technical Specifications for Ammonia Flue Gas Desulfurization Projects of Thermal Power Plant (HJ 2001-2010)
NOx	*Engineering Technical Specification of Flue Gas Selective Catalytic Reduction Denitrification for Thermal Power Plant' (HJ 562-2010)*
	Engineering Technical Specification of Flue Gas Selective Non-catalytic Reduction Denitrification for Thermal Power Plant' (HJ 563-2010)
PM	*Technical Specifications for Dedusting Engineering of Thermal Power Plants (HJ 2039-2014)*

8.2. Financial support

Due to the air pollution standards that were set forth, the Chinese government has focused on shutting down small, inefficient plants, and promoting clean technology. This adoption of clean technology such as desulfurization, denitrification and de-dusting equipment, has been subsidized through the industrial restructuring fund as well as purchase guarantees and premium tariff rates for low-emission power plants.

- General supports for the coal and power industry

Due to previous energy insecurity and power cuts, subsidies to the coal industry in order to provide stable, secure amounts of energy have become a mainstay in China. Subsidies to coal-fired power amounted to at least 252 billion CNY[75] in 2014, and 120 billion CNY in 2015. This amount of subsidization is close to double that provided for renewables[76].

There were a total of more than a dozen different subsidies to the coal sector between the years of 2013-2015. The ones relating to CFPPs are:1) Subsidies for investment in emissions abatement equipment; 2) Power purchase guarantee and premium rates for low-emission plants; and 3) A tax regime for coal power generation.

[75] For the exchange rate of CNY to the major currencies, please refer to http://x-rates.com/table/?from=CNY&amount=1; 1 CNY equals to circa 9.6261 INR, or 0.1448 USD, as of March 11th, 2017.

[76] Subsidies to Coal Power Generation in China. Global Studies Initiative. Link: https://www.iisd.org/gsi/renewable-electricity-subsidies/subsidies-coal-and-renewable-energy-china

Also, the Chinese banks are usually willing to give loans to the coal and power industry since they are mostly state-owned enterprises and have a large portion of fixed assets. According to the 2014 annual report from the Huaneng Power International, one of the Major Five Chinese powerCOs, the interest rate ranges from 4.20% to 6.55%[77].

- Subsidies on air pollutant abatement equipment

Subsidies for investment in emission abatement equipment are made in order to support the *'Law on Air Pollution Prevention and Control'*, and tax reductions have also been given to those who reduce SO_2, NO_x and PM emissions for compliance. This has led to a huge increase in emission reduction retrofitting, with around an 80% adoption rates of nitrogen dioxide reduction equipment and a 92% adoption rate of desulfurization equipment by the end of 2014.

In 2004, aiming for better environmental protection and meeting the financing gap, the central government set up the special funds to apply for, but the thermal power projects was not included in the first batch of industries. Since 2005, air pollutants control projects in thermal power sector was included[78], and the funds should be applied for and priority were given to the innovative technology deployment in desulfurization and denitrification. In addition, grants at the provincial level have been provided in order to enhance the penetration rate of the abatement equipment. These funds and grants are usually at no cost, and sometimes part of the grants was in the form of interest subsidy.

- Premium tariff rate for electricity from low-emission CFPPs

Premium prices are given to those generators which have been equipped with emissions control equipment and achieve emissions standards. The desulfurization tariff started in 2004, NRDC introduced the subsidy mechanism to encourage the installation of FGD on new CFPPs, at the rate of 0.015 CNY/kWh (circa 0.22 US cents) more on top of the on-grid tariff. In 2007, NDRC released the *'Measures for the Operation and Management of Desulfurization Electricity Tariff and Desulfurization Facilities for Coal-fired Generating Units (Interim)'* [79] to regulate the premium tariff since the implementation had certain flaws since 2004, both new CFPPs and the existing CFPPs equipped with verified desulfurization facilities could continue enjoy a desulfurization tariff of 0.015 CNY/kWh.

Based on the implementation of desulfurization electricity tariff, at the end of 2011, 14 provinces in China piloted the denitrification tariff to the new generation units to with installing denitrification facilities, at the rate of 0.008 CNY/kWh, and since January 1st 2013 the government decided to promote the measure to the nationwide. In August 2013, the NDRC raised the denitrification tariff to 0.01 CNY/kWh, since the power industry had lobbied by saying the previous rate of 0.008 CNY/kWh was too low to make up for the additional cost to run the equipments, and also the new 0.002 CNY/kWh price add-on for PM removal was proposed for consideration.

---

[77] 2014 Annual Report of Huaneng Power International, Inc. Link: http://www.hpi.com.cn/sites/english/reportYH/E_LTN20150420029.pdf

[78] Notice on Issuing the Guidelines for the Reporting of Special Projects for Environmental Protection. MEP 2005. Link: http://gcs.mep.gov.cn/zxzj/xmsb/200508/t20050818_69271.shtml

[79] Measures for the Operation and Management of Desulfurization Electricity Price and Desulfurization Facilities for Coal-fired Generating Units (Interim). NDRC 2007. Link: http://www.zhb.gov.cn/gkml/hbb/gwy/200910/t20091030_180711.htm (in Chinese)

In 2014, the *'Measures for the Operation of Environmental Protection Electricity Tariff and Environmental Protection Facilities for Coal-fired Generating Units'* were released[80], allowing the coal-fired generating units to build or transform environmental protection facilities to receive the so called 'environmental protection tariff' or 'green tariff', added on top of the normal power tariff. Not only was desulfurization equipment included but so were denitrification and dedusting equipment, and performance had to be verified by the environmental departments before receiving this premium rate. Since the 2014 measures, the green tariff level has been determined by the local government, and the current rate of green tariff in most provinces are 0.027 CNY/kWh, including 0.015 CNY/kWh for desulfurization, 0.01 CNY/kWh for denitrification and 0.002 CNY/kWh for PM removal.

Different from payment method of 'to give first and deduct later' of the desulfurization electricity price, denitrification electricity prices must be passed through the verification from the EPB, and then reported to the price bureau before getting the rebates on a quarterly basis. As a result, there is a slight lag in the process. At present, the PM removal price is similar to denitrification electricity rebates. In 2014, the actual subsidy in the form of green tariff amounted to over 94 billion CNY, and if taking into account of each kWh of electricity is subsidized with the green tariff, then as for 2014 the government needed to to subsidize about 113 billion CNY to the CFPPs[81], which means more than 83% of total generated power had been subsidized under the green tariff scheme.

Due to the huge amount of subsidies given to the thermal power sector, NDRC realized that stricter supervision of the tariff subsidies should be in place. Since 2015, NDRC has ordered the provincial price bureaus and EPBs to jointly inspect the power generation enterprises and power grid enterprises in terms of green tariff scheme implementation. According to the NDRC website, the latest inspection of 2015 implementation status took place during May to October 2016 [82], the focus of the inspection contents was to check the compliance status of CFPPs, CEMS data misconduct, and grid companies' implementation of rebating the green tariff.

Special incentives for ultra-low emission CFPPs

Coal-fired power plant ultra-low emissions has been included in the Prime Minister's government work report for the State Council for two consecutive years. Therefore, the NDRC, NEA and MEP together proposed to introduce an ultra-low emission unit tariff subsidy policy. All ultra-low emission CFPPs connected with grid before January 1st 2016 can enjoy additional premium, 0.01 CNY/kWh. For the ultra-low emission CFPPs connected with grid after January 1st 2016 enjoy additional premium, 0.005 CNY/kWh[83].The guarantee for power purchase and premium rates for ultra-low emissions plants have allowed for those plants that make the transition to retrofitting emissions reduction equipment, and the premium payments will be paid directly from the Power Grid on a per hour basis when ultra-low emissions standards are achieved.

---

[80] Measures for the Operation of Environmental Protection Electricity Tariff and Environmental Protection Facilities for Coal-fired Generating Units. NDRC 2014. Link: http://jgs.ndrc.gov.cn/zcfg/201404/t20140403_605765.html (in Chinese)

[81] Thermal power plants cheated: Two ministries to start a special inspection of environmental protection. May 18th 2016. Link: http://china.caixin.com/2016-05-18/100944677.html (in Chinese)

[82] NDRC and MEP organized the national electricity environmental protection price special inspection. Link: http://jjs.ndrc.gov.cn/gzdt/201605/t20160516_801776.html (in Chinese)

[83] Implementation of coal-fired power plant ultra-low emission price support policy. NDRC 2015 NO. 2835. Link: http://www.sdpc.gov.cn/zcfb/zcfbtz/201512/t20151209_761936.html (in Chinese)

Investments on Installing APCDs at CFPPs

As the key financial initiative to support CFPPs to install and fully operate pollutants removal facilities, the premium desulphurization tariff scheme often faces challenges in implementation. Firstly, the one-time capital investment is often huge in size. Quoting from a case study done by a researcher from China Datang Science and Technology Research Institute, affiliated to Datang Group, which is one of the Major Five Power Corporations in China, the capital investment is 170 million CNY for the FGD system, accounting for 11.7% of the total investment of this CFPP. Secondly, the declining annual operation hours cannot support power plants to maintain the annual operation of facilities. As **Table 22** shows, the plant with 600 MW capacity could be entitled 5.7 million CNY of gross profit only by maintaining high annual operation hours of more than 7,000 hours. Unfortunately, in 2016 the average operation hours for CFPPs was around 4100 [84], which will make the operation of the desulfurization facilities less profitable but of course the CFPPs should bear the cost of complying the emission standards no matter whether they could earn money from running the APCDs.

Table 22: An Economic Analysis of Desulfurization Facilities in a 600MW CFPP

	Profile	Cost	Income	Gross Profit
		(in million CNY)		
Unit number/ Unit capacity	2 / 300 MW			
Electricity generation (MWh)	4.23 million			
Annual operation hours	7050			
Electricity use rate by the plant	6%			
Transformer loss rate	10%			
Premium tariff (CNY/kWh)	0.015			
Depreciation period (years)	30			
Facilities depreciation		5.67		
Material supplies		5.35		
Electricity use to support facilities		23.7		
Personnel to maintain the facilities		3		
Maintenance		6		
Pollution charges for SO_2 and wastewater		3.1		
Other cost		0.8		
Cost subtotal		47.6		
Revenue from premium tariff			53.3	
Gross Profit				5.7

Source: Yuan Yuan., The Economic Analysis of Wet Sulfurization Application in Coal-Fired Power Plant and the Third Party Service: A Case Study. Link: http://www.cnki.com.cn/Article/CJFDTotal-DLQB201601006.htm (in Chinese)

[84] CEC China Electricity Statistics 2016 on CEC website. Link: http://english.cec.org.cn/

8.3.Penalties for delay or non-compliance

Some provinces and municipalities have introduced the relevant provisions of using CEMS data as evidence for administrative penalty for the automatic monitoring of pollution sources, such as Liaoning Province, Shanxi Province and Chongqing Municipality. Local EPBs have different tolerance levels for polluters whose CEMS data exceed the limits before releasing the administrative penalties, using the accumulated exceeding standard base points, and/or accumulated and continuous hours of exceedance over the assessment period. The rules are still being developed and varied among the EPBs, some provinces and cities such as Hubei and Liaoning Provinces, Foshan City have made some progress. For instance, Liaoning Provincial EPB had enacted the *'CEMS Data Applicable to Environmental Administrative Penalties Approach (Interim)'* [85], the following paragraph present the detail in penalty conditions for air pollutants including SO_2 and PM, but not NOx at the moment.

> Air pollutants CEMS monitoring data appears any one of the following circumstances, the entity should be commanded to comply with the standard before the deadline, and be punished according to the following terms within the assessment period (15 days):
>
> - CEMS data intermittently exceed the standard base point (hourly average CEMS data) 5 times or less, a warning will be given, but if there is a continuous exceedance of 3-5 base points, 30,000 CNY fine will be applied;
> - exceeding more than 5 times in accumulation but less than 10, a fine of 10,000 CNY to be imposed; but if there is a continuous exceedance of 6-10 times to the basis points, a fine of 50,000 CNY;
> - exceeding more than 10 times in accumulation but less than 20, a fine of 30,000 CNY to be imposed, but if there is a continuous exceedance of more than 10 times to the basis points, a fine of 100,000 CNY;
> - exceeding more than 80 times in accumulation over the standard base points, a fine of 100,000CNY.

At the central level, the Ministry of Environmental Protection will verify the implementation of major pollutants emission reduction of the CFPPs on an annual basis, and the verification results and penalty notices will be shown on the MEP's website, for example in 2014 the MEP listed that 46 power plants from seventeen power corporations whose desulfurization and denitrification facilities did not fulfill the requirements by exceeding emissions standards, providing unreliable CEMS data, or having equipment malfunctions[86].

The requirements and penalties for non-compliance include the following measures:

1) The non-compliant enterprises shall complete the rectification and reform plan for the FGD facilities within 30 working days from the date of announcement, and report to the MEP, the Regional Environmental Protection Supervision Center and the provincial EPB. By the end

[85] Liaoning Province CEMS Data Applicable to Environmental Administrative Penalties Approach (Interim). Link: http://www.lnepb.gov.cn/hjgl/zfjc/hjzf/201011/t20101111_18827.html (in Chinese)

[86] Announcement on the Punishment of Enterprises with Prominent Problems in FGD Facilities in 2014. MEP June 23rd 2015. Link: http://www.mep.gov.cn/gkml/hbb/bgg/201506/t20150625_304287.htm (in Chinese)

of each compliance year, if it fails to do so within the time limit, it shall be punished severely according to law;

2) Within 15 working days as of the date of the penalty announcement, the provincial EPB should determine the amount of SO_2 and NOx discharge fees to be paid in full based on the actual discharge and publicly show the discharge fee surrendered;
3) Within 30 working days after the announcement, in accordance with the relevant provisions of the *'Measures for the Operation and Management of Desulfurization Electricity Tariff and Desulfurization Facilities for Coal-fired Power Generating Units'* and the *'Regulatory Measures on Environmental Tariff for Coal-fired Power Generating Units Using Environmental Protection Facilities'*, the provincial EPB should ask the non-compliant enterprises to return the difference of environmental protection electricity prices.
4) As for the abnormal operation of the desulfurization and denitrification device, or the abnormal use of CEMS, monitoring data fraud, and pollutants over discharge, local environmental protection departments shall fine the non-compliant enterprises based on what are required in Article 46 of the *'Law on Air Pollution Prevention and Control'* and Article 18 of the *'Measures for the Automatic Monitoring and Control of Pollution Sources'*.

The new '*Environmental Protection Law*' more specifically guarantees the public rights to environmental knowledge, requiring environmental departments to disclose their data and mandating information disclosure of pollution emissions. Additionally, environmental groups that are registered at the municipal level or provincial level government are allowed to bring forward lawsuits regarding environmental damage, allowing the public to hold both the government and industry more accountable. One of the most important changes to the law was the increase in penalties. Initially, environmental penalties were so low that non-compliance cost less to industries than compliance, rendering their enforcement quite hard. However, the new law used similar provisions to the US environmental law, allowing penalties to accumulate each day after the polluter receives a compliance order, quite a contrast to the previous set fines that did not accumulate with further non-compliance. The hope of this change in law is to reduce delays in non-compliance, and to properly economically value non-compliance[87]. Finally, stricter punishments for government and administrative offenses to the law, such as detention, potential criminal penalties, or removal from their post[88].

However, the issue of weak enforcement will be a long-lasting concern, with a total of over 3,000 environmental protection bureaus and 180,000 staff members at the local level, but only 400 employees in the Ministry of Environmental Protection to monitor these local level groups, the implementation of laws and regulations is often their downfall due to corruption and local protectionism[89]. Therefore, adequate amounts of central government employees in order to ensure the implementation of laws is necessary; the proper monitoring system needs to allow for standardized regulations throughout the country.

[87] The 2014 Revisions of China's *'Environmental Protection Law'*. Link: http://www.gov.cn/xinwen/2014-04/25/content_2666328.htm(in Chinese)

[88] New Weapons in the War on Pollution: China's Environmental Protection Law Amendments. NRDC. Link: https://www.nrdc.org/experts/barbara-finamore/new-weapons-war-pollution-chinas-environmental-protection-law-amendments (in Chinese)

[89] The 2014 revisions of china's environmental protection law. Tseming Yang. Link: http://cgd.swissre.com/risk_dialogue_magazine/Environmental_liability/The_2014_Revisions_of_Chinas_Environmental_Protection_Law.html

8.4.Preferential dispatch policies based on a plant's pollution load and/or efficiency

The State Council released the *'Dispatch Regulation of Energy-saving Electricity (Interim)'* in 2007 [90], and selected several provinces such as Jiangsu and Guangdong to trial this dispatch regulation, later in 2008 information regarding this approach was published. According to this dispatch regulation, priority was given to the renewable power generation resources first, then by the order of energy consumption and pollutant discharge level of the fossil power plant.

As for the same type of coal-fired power units, the dispatch priority is ranked in accordance with the level of coal consumption rate, for the same rate of coal consumption in power generation, units with lower pollutant emissions level should go on grid first. And the coal consumption level of the unit operation will be first adjusted according to the unit coal consumption parameters provided by the equipment manufacturer and gradually adjusted to the actual measured value. Pollutant emission levels should be decided by the latest measurements monitored by provincial EPBs.

In 2014, the NDRC together with the NEA released the *'Interim Measures for Alternative Management of Reduction of Coal Consumption in Key Areas'*, explaining that the utilization hours will be increased for generating units achieving higher energy efficiency and environmental protection targets. When the CFPPs reach the ultra-low emissions level, they will be entitled more utilization hours and therefore more on-grid electricity in the next year.

8.5.Implementation of cap and trade programs for controlling air pollutant emissions

China began to pilot an air pollutant emissions trading platform in mid-1990s. The pilot area expanded from the city level to provincial level, and in recent years the faster pace is seen in the eastern, central and northern China.

The 2009 and 2010 governmental work report began to mention and expand the emissions trading pilots. In 2011, the relevant policies were more intensively made for the *'12th Five-Year Plan'*, and these policies mentioned the development of emissions trading market, regulation of the price behavior of emissions trading, and improvement of environmental economic policies and environmental regulations system.

In summary, between 2007 and 2014, provinces and municipalities issued a total of 18 regulations and more than 70 policy documents, stipulating the validation of the emission rights, pricing design, the initial allocation approach, trading rules and transaction management requirements. By the end of 2013, the total amount of emissions trading transactions in the pilot provinces has accumulated nearly 4 billion CNY.

In Shanxi province, for example, according the provincial pollutant emissions trading information, the total amount of SO_2 trading in 2013 reached more than 62 million CNY, and NOx amounted to 130 million CNY.

[90] Dispatch Regulation of Energy-saving Electricity (Interim), 2007, State Council. Link: http://www.gov.cn/zwgk/2007-08/07/content_708486.htm (in Chinese)

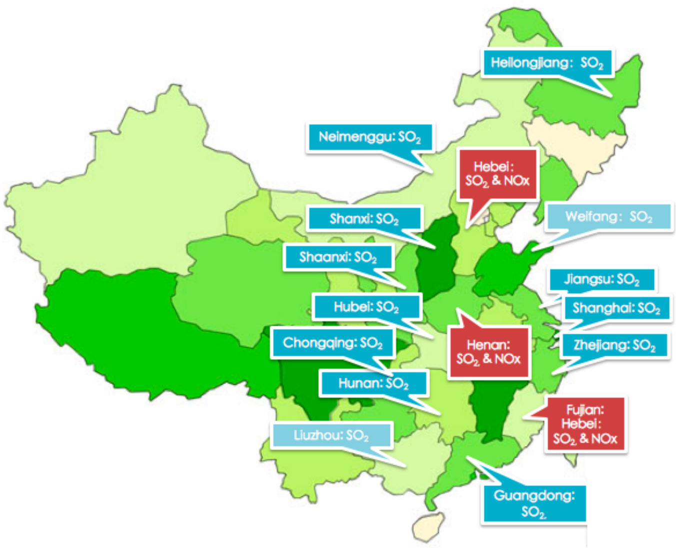
Table 23: Pollutants Emissions Trading Information in Shanxi (2013)

Pollutants	Volume (tons)	Price (CNY/ton)	Value (CNY)
SO_2	3,476	18,000	62,568,000
NOx	6,847	19,000	130,093,000
COD	350	29,000	10,150,000
NH_3-N	46	30,000	1,380,000
PM	1,407	6,000	8,442,000
Industrial PM	1,337	5,900	7,888,300
Sum			**220,521,300**

Source: Shanxi EPB Pollutants Emissions Trading Center

At present, air pollutant emissions trading in the provinces and municipalities at all levels of the pilot are included in the SO_2, but only Hebei, Henan and Fujian provinces have NOx emissions trading. **Figure 14** summarizes the pilot provinces/municipalities of the domestic air pollutant emissions trading schemes in place by the end of 2015.The thermal power sector is one of the key actors in air pollutants trading.

Figure 14: Distribution of SO_2 and NOx Trading Schemes in China



Source: Author's own analysis

<u>Development of pilots in pollutants emissions trading system</u>

As shown in the above map, emissions trading of pollutants has been carried out in some 16 pilot provinces and municipalities, mainly for SO_2 and NOx emissions trading; however, the current trading activities of domestic emissions trading market is not active, and there has been obvious differentiation among the pilots, mainly due to the imbalanced regional development, different enforcement power of the local EPBs, and enterprises often being reluctant to sell the surplus.

According to the publicly obtained information from local EPBs, the current development of the pilots is summarized in the following table:

Table 24: Summary Information of China Domestic Pollutants Emissions Trading Pilots

Pilot Area	Status and Future Development	Approval and Allocation of Discharge Permit	The Impact on Business
Shanxi	*Administrative Measures of Initial Emission Permit Approval and Trade (2009)*, *Implementing Regulation of the Main Pollutant Emission Trading (2011)*, trading platform and trading benchmark price (2013), audit of pollution discharge right, and the classification management of government's pollution discharge right reserve (2014). The allocation plan and the regulations of monitor and validation are still being developed.	Based on the emission of in the 2010 pollution database, or the amount of major pollutants clarified in the discharge permit. The quotas shall be approved and distributed once every five years.	Companies need to pay for discharge permits, excess of the allowed emissions from the permit needs to be obtained through purchase, and companies may also face fines from environmental protection department.
Zhejiang	*Interim Measures for Pollution Discharge Certificate (2010)*; Procedures of compensated use of pollution discharge right, *Regulation on the Procedures of Internal Audit of Pollution Discharge Right (2011)*, *Technical Standards for Initial Emission Permit Approval and Distribution (2013).* Currently, the cities have not been interconnected, but the regulations will cover the whole province in the future.	Mainly based on the amount of the discharge permit approved by the EIA. Also, refer to the amount of pollutant discharge at the completion, the registered amount of pollutant discharge, the amount of environmental statistics in 2013 and the updated amount of pollution in 2010.	Take Hangzhou as an example, since companies need to buy all the emission rights, the cost of production will further increase, but the emission right, as an asset of a company, can be transferred, sold, leased or used as a mortgage.
Guangdong	*Administrative Measures of Compensated Use of Pollution Discharge Right and Trading Pilots (2014), Regulation for Pollutant Emission Trading (2015),* The compensated use and trading of Sulfur dioxide discharge right would be applied in the whole province and the provincial environmental protection authorities responsible for the implementation.	The initial allocation of emission rights is subject to grading responsibility. Environmental protection departments at all levels approve and allocate initial emission permit, in accordance with the authority and the unified provincial allocation rule.	The enterprises participating in the pilot scheme of emissions trading are not exempt from their responsibilities of pollution control, payment of emission charges, pollution abatement and other responsibilities required by laws and regulations.
Hunan	*Administrative Measures of Compensated Use and Trading of Pollution Discharge Right and Capital Management (2014).* Currently, the province is continuing to promote the compensated use, to regulate the approval, the trade of discharge right, the capital management and the monitor. The trading platform of discharge right has been built and emission rights mortgage business has been officially launched, though not perfect.	The provincial Environmental Protection Office approve and distribute the emission permits to the thermal power plants with more than 200,000 kilowatts capacity, after the enterprise declaration, the public city and procedures of audit done by the environmental protection department. Clearly regulates that the main pollutant emissions compensation fee is the payment for state-owned resource.	Due to the primary stage of development, enterprises are not familiar with the concept of emissions trading; need to gradually improve the enterprises' understanding of "environmental resources are limited, valuable, and need to be paid".

Hubei	*Implementing Regulation of the Main Pollutant Emission Trading (2012), Main Pollutant Emission Electronic Bidding and Transaction Rules (2014), Implementing Regulation of the Main Pollutant Emission Trading (2014-2020)*, establish basic institutions of pollutant emission trading till 2017 and fully implement the institutions by 2020. Currently focused on the market bidding transaction for new project emission targets.	The administrative departments of environmental protection at all levels shall, following the relevant provisions of the initial emission control of the major pollutants in Hubei Province, approve and allocate the initial emission rights of the main pollutants to the sewage units in accordance with the principle of classification management.	The enterprises who achieve actual annual emission of main pollutants less than the annual allowed emission through implementing process updates, cleaner production and strengthening pollution control, can apply to local environmental protection administrative departments for emission reduction registration, the reduced emission can be traded or reserved.
Hebei	Submitted the report on *Compensated Use of Pollution Discharge Right and Trading Pilots (2014)*, started the approval procedures of the main pollutant emission total amounts in construction projects (2014), Provincial Environmental Protection Office will establish the province's construction project major pollutant emission target management platform, implement dynamic management, according to the project specific information. City and county environmental protection bureaus would carry out the relevant audit work within this framework.	For the construction projects, the total pollutant emission quotas shall be obtained before the approval of the environmental impact assessment documents. If certain construction projects need the permit for new annual emissions of major pollutants, it can only be obtained through transaction.	At present, Hebei Province's emissions trading requires enterprises to obtain the increased main pollutant emission through transaction with other enterprises, compensated use for main pollutants has not yet started, the current annual emission permit target is still free for the enterprises.
Shaanxi	The compensated use and trading of Sulfur dioxide discharge right has been launched (2010), more detailed trading administrative measures (2014). Currently, focused on market bidding transaction for new project emission targets. Mortgage financing of the emission discharge for the first time in Shaanxi.	The administrative department of environmental protection shall issue or change the sewage permit based on the results of the emissions trading.	Shaanxi Province is trying to use the transaction fund, gained from emission trading, to encourage high energy consumption, high-polluting enterprises to close out.
Inner Mongolia	*Administrative Measures of the Pollution Discharge Right Reserve Management, Trading Rules, Electronic Biding Rules (2010)*, *Plan for the Compensated Use of Pollution Discharge Right and Trading Pilots (2014). By* Jan. 2015, the compensated use and trading of pollution discharge right took effects.	With the approval of the environmental authorities, the existing sewage units obtain the emission right after paying compensation of emission. For new, reformed and expanded projects, which need more quotas, the permit can be obtained through transaction, with the approval of the environmental departments.	Enterprises that have gained the emission licenses have to pay the emission rights when they renew the license. There may be contradictory rules if the policy adjustment is not smooth. In addition, the prices tend to be high during the auction.

Source: Compiled by REEI using public information from provincial EPBs

In August of 2014, the State Council released an order that was the turning point for further promotion of air pollutants emissions trading, the '*Guidance on Further Piloting the Pollutant*

Discharge Permit and Trading of Emission Permits'[91], which determined the timeline for the establishing emissions trading system, and the stagnant situation of multi-pilot mode was expected to break through for national emissions trading.

9. Future Policy Trends for Environmental Governance in the Chinese Sector

According to the *'Electric Power Development 13th Five-Year Plan'*, there is a new projected coal power capacity of 10 GW by 2020, meaning coal will playa decreasing role in the next decade. One major reason for this is the concern for the environmental impacts from the Chinese Sector. The incremental increases electricity demand will be met by wind power, solar PV and other renewable energy sources. Coal originated electricity will take the main responsibility to maintain grid load stability. Also, with the current power market reform and the decreasing cost of renewable energy power generation, coal power's competitive advantage is already being and will continue to be challenged in the future.

9.1.Further tightening of existing standards

According to the Ministry of Environmental Protection statistics, as of the end of 2015, the country has nearly 100 GW of coal-fired power units that have completed the ultra-low emission technological transformation. According to the *'13th Five-Year Plan on Energy Development'*, the completion of ultra-low-emission coal-fired power plant transformation should reach 420 GW. The MEP released the *'Full Implementation Plan of Ultra-Low-Emission Coal-Fired Power Plants and Energy-Saving Retrofitting Program'* at the end of 2015, aiming to accelerate the progress of CFPPs in achieving a nationwide ultra-low emission standard and necessary upgrading measures for energy conservation purpose[92].

According to the Plan, the future emission standards for the coal power system in China would be meeting ultra-low-emission requirements with PM, SO_2 and NOx below 10, 35 and 50 mg/m^3 respectively. The target timeline is that all of the country's CFPPs with the conditions to transform will strive to achieve ultra-low emissions by 2020, and all the new coal-fired generating units should achieve ultra-low emission levels. To speed up the pace of ultra-low emissions retrofitting of existing coal-fired generating units, the eastern region (11 provinces/municipalities)will aim to complete the ultra-low emission upgrade by 2017, the central region (8 provinces/municipalities) will strive to complete by 2018, and the western region, the least developed 12 provinces/ municipalities, will try to meet the target by 2020 (**Table 25**).

The year of 2017 is a vital year of achieving ultra-low emission retrofitting. The eastern region is to meet the conditions of transformation to ultra-low emission by the end of this year, and the transformation of the western region is promoted to peak this year.

[91] Guidance on Further Piloting the Pollutant Discharge Permit and Trading of Emission Permits. MEP 2014. Link: http://www.gov.cn/zhengce/content/2014-08/25/content_9050.htm (in Chinese)

[92] Notice on 'Full Implementation Plan of Ultra-Low-Emission Coal-Fired Power Plants and Energy-Saving Retrofitting Program' December 11th 2015, MEP. Link:http://www.mep.gov.cn/gkml/hbb/bwj/201512/t20151215_319170.htm (in Chinese)

Table 25: Requirements and Schedule of Retrofitting to Ultra-Low Emission CFPPs

Location of the CFPPs	Installed Capacity Requirements	Completion Timeline
The eastern region (Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan)	All existing 30MW and above public CFPPs; non-public 10MW and above CFPPs.	By the end of 2017
The central region (Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan)	All existing 30MW and above public CFPPs	By the end of 2018
The western region (Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang)		By the end of 2020

Note: Temporarily excluding W-type flame boiler and circulating fluidized bed boiler. Adapted from 'Full Implementation Plan of Ultra-Low Emission Coal-Fired Power Plants and Energy Saving Retrofitting Program'

While cost-effectiveness should be considered since retrofitting to Ultra-Low Emission will cost as much as 0.24% of the Chinese GDP (2014) according to the study done by the researchers in Peking University[93], the results showed that the pollutant-mitigation costs are around 44,600 CNY per ton of SO_2, 23,500 CNY per ton of NOx, 4,300 CNY per ton of PM, and it would be costly to implement the ultra-low emission transformation in the whole power industry. They also suggested that the government should initiate to implement the Ultra-Low emission transformation from the smaller power plants with dirtier coal quality.

9.2.Introduction of cap and trade programs

To implement the order from the National Council on the reinforcement of pollutant discharge permit system, the Ministry of Environmental Protection released the '*Circular on Printing and Distributing the Interim Provisions on the Administration of Pollutant Discharge Permits*' at the end of 2016[94], aiming to provide the details of the operation of the new discharge permit system. In early January 2017, the MEP released the order to emphasize power and paper industries as the leading sectors to exercise the permit system[95]. These latest moves in the pollutant discharge permit system have shown the resolution of the government in controlling the total amount of the pollutants from key industries, establishing a sound MRV system, and using market mechanisms to solve the air pollution issue from the Chinese sector and among others.

93 ZHAO Dong-yang, JIN Ya-na, ZHANG Shi-qiu Cost-effectiveness analysis of pollution emission reduction measures and ultra-low emission policies for coal-fired power plants. *China Environmental Science*. 2016,36(9):2841~2848. (in Chinese)

94 Circular on Printing and Distributing the Interim Provisions on the Administration of Pollutant Discharge Permits, MEP December 23rd 2016. Link:http://www.zhb.gov.cn/gkml/hbb/bwj/201701/t20170105_394012.htm (in Chinese)

95 Notice on Carrying out the Management of Emission Permit for Elevated Sources of Thermal Power, Paper Industry and Beijing-Tianjin-Hebei Pilot City, MEP January 5th 2017. Link:http://www.zhb.gov.cn/gkml/hbb/qt/201701/t20170106_394017.htm (in Chinese)

9.3.Scheduled retirement of existing plants

As mentioned in the beginning of the report, under the '*13th Energy Development Five-Year Plan'*, there will be no new CFPPs to be approved for the first two years, and the total coal power capacity is expected to remain below 1,100 GW by 2020. In addition, it is estimated that by 2020 the Chinese Sector will see a capacity of 420-580 GW of CFPPs retrofitted to ultra-low emission and efficiency upgrading of 340 GW of CFPPs, with an annual closure of 4 GW of obsolete capacities during 2016 to 2020, totaling 20 GW [96,97].

According to relevant provisions in the *'Notice on Improving the Orderly Development of Coal-fired Power Plants'* by the NDRC and the NEA, the Chinese government is going to phase out obsolete CFPPs which have served a long life, and failed to meet the requirements in energy efficiency, environmental protection and safety. The priority will be given to CFPPs below 300 MW that have been operating for over 20 years of pure condensate unit and pumping condensate units.

[96] Energy development in the 13th Five-Year Plan issued to adhere to six 'pay more attention to' policy orientation. Link: http://finance.china.com.cn/news/20170105/4056538.shtml (in Chinese)

[97] Notice of the State Council on the Work Program of Energy Saving and Emission Reduction in the 13thFive-Year Plan. Link:http://www.gov.cn/zhengce/content/2017-01/05/content_5156789.htm (in Chinese)

Appendix 1: Evolution of China's Air Pollution Policies

Major policies related to air pollution and air quality are listed here according to the chronological order:

Year	Policies Related to Air Pollution
1982	Set the limits for TSP, SO_2, NO_2, lead and BaP
1987	*'Law on Air Pollution Prevention and Control'*
1989	*'Environmental Protection Law'*
1991	*'Emission Standard of Air Pollutants for Thermal Power Plants'*
1995	*'Law on Air Pollution Prevention and Control'* (First Amendment)
1996	*'Emission Standards of Air Pollutants for Thermal Power Plants'* (First Amendment)
2000	*'Law on Air Pollution Prevention and Control'* (Second Amendment)
2003	*'Emission Standard of Air Pollutants for Thermal Power Plants'* (Second Amendment)
2006-2010	• *'11th Five Year Plan'* (with emphasis on coal power plant efficiency) • *'Emission Standards of Air Pollutants for Thermal Power Plants'* (Third Amendment)
2012	• AQI (Air Quality Index) to include PM and Ozone in replacing API (Air Pollution Index) • First $PM_{2.5}$ limitations set forward under the *'National Ambient Air Quality Standards'* (NAAQS) ○ standards took effect at different rates throughout the country ○ 2012: Beijing-Tianjin-Hebei, Yangtze River Delta, Pearl River Delta, provincial capitals ○ 2014: key environmental protection cities ○ 2015: prefecture-level cities ○ 2016: nationwide implementation • Five Year Plan includes clean energy and sustainable growth plans • 'Airpocalypse' happened in December in Beijing
2013	• Start to publish monitoring results of $PM_{2.5}$ across 74 cities • At the State Council Executive Meeting, Premier Li Keqiang establishes 10 major air pollution measures, namely the 'Air Pollution Prevention Action Plan', mandating 15-25% $PM_{2.5}$ reductions in key cities and 10% PM_{10} reductions in all other cities by 2017 per a 2012 baseline
2014	• Coal Mining Capacity Retirement • Coal Fired Power Generation Action Plan (emissions standards for new coal fired plants) • *'Law on Air Pollution Prevention and Control'* (Third Amendment), cancellation of all coal subsidies • US-China joint announcement to peak CO_2 emissions • *'Interim Measures For The Administration Of Coal Consumption Reduction In Key Regions'* established hard coal caps in Key Regions
2015	• New *'Environmental Protection Law'* put into effect (amended in April 2014) • *'Industrial Clean Coal Utilization Action Plan'* as the roadmap for emissions and efficiency standards for heavy industry coal use • *'Clean Coal Utilization Plan'* combined all smaller coal oriented policies from the past few years
2016	*'Law on Air Pollution Prevention and Control'* (amended in August 2015)

Source: Author's own analysis

Appendix 2: China National Ambient Air Quality Standard (*GB 3095–2012*)

Air Pollutants Category	Grade I	Grade II
SO_2 (μg/m^3)		
Annual Average	20	60
24 h Average	50	150
1 h Average	150	500
NO_2 (μg/m^3)		
Annual Average	40	40
24 h Average	80	80
1 h Average	200	200
CO (mg/m^3)		
24 h average	4	4
1 h average	10	10
Ozone (μg/m^3)		
8 h maximum	100	160
1 h average	160	200
PM_{10} (μg/m^3)		
Annual Average	40	70
24 h Average	50	150
$PM_{2.5}$ (μg/m^3)		
Annual Average	15	35
24 h Average	35	75
TSP (μg/m^3)		
Annual Average	80	200
24 h Average	120	300
NOx(μg/m^3)		
Annual Average	50	50
24 h Average	100	100
1 h Average	250	250
Pb		
Annual Average	0.5	0.5
Quarter Average	1	1
BaP		
Annual Average	0.001	0.001
24 h Average	0.0025	0.0025

Source: China's National Ambient Air Quality Standards (GB 3095–2012).
Link: http://kjs.mep.gov.cn/hjbhbz/bzwb/dqhjbh/dqhjzlbz/201203/W020120410330232398521.pdf(in Chinese)

Website: www.reei.org.cn
Email: info@reei.org.cn
Telephone: +86(10)61438032
Address: Houshayu,Shunyi,Beijing,
101318,P.R.China