INTEGRATED AIR PURIFIER FOR CONTROL AIR POLLUTION ODOR IN LIVING ENVIRONMENT

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Abstract:

To explore the atmospheric emissions of coal-fired power sector in China, a unit-based method was developed based on detailed information of unit type, fuel quality, emission control technology, and geographical location. During the period when power sector developed fastest in the past 20 years, SO2, Nox and PM emissions of coal fired power plants increased by 1.5, 1.7 and 1.2 times, respectively. The SO2, emission of coalfired power sector was estimated to be 16 097 kt in 2005, and would decrease to 11801 kt in 2010, attributed mainly to the wide application of the flue gas desulfurization (FGD) technology. The NOx emission, however, would increase since few Nox control measures would be taken during the five years. The TSP, PM10, and PM emissions in 2005 were estimated and the values would be 2540, 1824 and 1090 kt in 2010 respectively. The wet FGD would play an important role on dust emission removal. Through faithful implementation of closing small units and emission control policies in the acid rain and sulfur dioxide control zones, approximately 33%, 6% and 25% of SO2, NOx, and TSP emissions respectively could be further reduced in 2010. Emissions in 2015 and 2020 of coal-fired power plants were predicted applying scenario analysis. For SO2 and TSP, optimistic situation can be achieved through reasonable control policies; contrast, NOx would probably be a more serious issue in future.

Introduction

Coal-fired power plant has been considered as a very important source of regional air pollution and ecosystem acidification, due to its huge emissions of acidic pollutants. A series of studies have used top-down method to estimate the emissions of SO2 (Wang, 2001; Streets et al., 2003; Ohara et al., 2007), NOx (Hao et al., 2002; Tian, 2003; Streets et al., 2003; Ohara et al., 2007; Zhang et al., 2007a) and PM (Zhang et al., 2007b; Yi, 2006a) from Chinese power sector around year 2000 or before. On one

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hand, most of those studies treated power plant as one single sector in an anthropogenic emission inventory framework. They generally ignored the discrepancy of technology and fuel characters among power units of different types, which can be of great effect on emission levels. On the other hand, those studies did not reflect the rapid increase of coal consumption and electricity generation since 2000, and the results were no longer applicable for policy making in the future.

With increasing environmental pressure, Chinese government has made the decision that coal-fired power sector would be the most important source of regional atmospheric emission abatement in the near future, and power plants are thus anticipated to face more stringent environmental regulations related to siting and operation. To supply a clear emission picture of power sectors for policy making, this study explored the current and historical emissions of power plants as well as the emission control effects of possible policies throughan innovative unit-based method. The future power sector emissions till 2020 were tentatively predicted through scenario analysis, considering different levels of energy consumption andcontrol measures.

Methods

Unit-based methodology

The studied regions covered 31 provinces over mainland China. Hong Kong, Macao and Taiwan were not included since detailed information of those areas was not available. SO2, NOx, and PM were the target species. Different from previous studies, emissions were estimated through a

bottom-up unit-based methodology. A Chinese power sector database was established, in which all the information related with emissions was compiled at unit level, including geographical location, capacity, boiler type, starting year, annual running hour, fuel type, sulfur content, coal consumption per unit electricity-supply, and emission control technology of SO2, Nox and PM. The total capacity of coal-fired power plants was 230 and 356 Gwin 2000 and 2005, respectively. The data between 2001 and 2004 were deduced according to the information of newly built or retired units in corresponding years. In 2010, the national capacity of coal-fired power plants would be expected to increase by 90% and reach 681 GW compared with that in 2005. Annual emission of each unit was seriatim calculated based on unit-specific fuel consumption and emission factor, and then aggregated to regional level. Emissions of SO2, NOx and PM from power plants at province level were calculated using Eqs. (1)–(3) respectively.

$$E_{SO_2,i} = \sum_j A_{j,i} \times Scont_{j,i} \times (1 - Sr) \times (1 - \eta_j) \quad (1)$$

$$E_{NO_x,i} = \sum_k \sum_m \sum_n A_{i,k,m,n} \times EF_{NO,k,m,n} \quad (2)$$

$$E_{PM,y,i} = \sum_k \sum_n A_{i,k} \times AC_i \times (1 - ar_k) \times f_{k,y} \times C_{k,n} \times (1 - \eta_{n,y}) \quad (3)$$

where subscripts i, j, k,m, n, and y stand for province, power unit, boiler type, fuel type, emission control technology and particulate size; EF is the emission factor; A is the coal consumption; C is the application rate of emission control technology; h is the removal efficiency of emission control technology; Scont is the sulfur content of fuel; Sr is the sulfur retention in ash; AC is the ash content of fuel; ar is the ratio of

bottom ash; and f is the particulate mass fraction by size.

Activity level

As the coal consumption of each unit was estimated according to its annual operation hours and coal consumption per unit electricity-supply. For the unit lack of these two parameters, national average values were applied. As shown in Fig. 1, the average annual operation hours of Chinese coal-fired power plants increased from 4900 to 5800 h during 2000–2005. However it dropped quickly to 5300 h in 2007, since the operation of newpower plants has alleviated the pressure on electricity-supply and thus lowered the average operation hours. In this study, the annual average operation time was assumed to be 5100– 5200 h in 2010. Regarding the consumption rate, the national average values for units smaller than 100MW, 100 200MW, 200–300MW, 300–600MW, and larger than 600MW were respectively 440, 379, 365, 335 and 326 gce kWh_1.[1] With rapid increase of large units, the national value declined from 392 to 357 gce kWh_1 during 2000–2007 (NBS, 2006). In this study, the national average value was calculated to be 353 gce kWh_1 in 2010 according to the unit fractions by size and corresponding coal consumption rates.

$$A_j = 1.4 \times U_j \times T_j \times E_j \times 10^{-6}$$

where A is the coal consumption (kt); U is the unit size (MW); T is the annual operation hours; E is specific coal consumption per unit electricity-supply (gce kWh_1). National coal consumptions of power sector during 2000 and 2010 are shown in Fig. 2. In 2005, the national coal consumption of power sector was 1069.7 Mt, and it would reach 1735.2 Mt in 2010,

with an annual average increase rate of 10.2%. Moreover, significant variation on distribution by unit sizewas found. Due to the construction of large units, the coal consumption of units larger than 600MW in 2005 only accounted for 11.2% and the value would increase to 37.0% in 2010, while the share of units smaller than 100MW would decrease from 23.8% to 11.2%.

Emission factors

As the sulfur content (Scont) of fuel is the key factor influencing SO2 emissions. In this study, the data of sulfur content were obtained from each specific unit. Fig. 3(a) shows the sulfur content distribution by each province in 2005. Relatively high-sulfur content was found in southwestern China, while northeastern was the region with lowest sulfur content. The national average sulfur content of coal used by power sector was 1.01% in 2005. Confirmed by the field measurements by Tsinghua University (unpublished yet), the sulfur retention ratio (Sr) during the combustion process of power plants was determined as 0.05–0.10. Another factor influencing SO2 emissions is the application rate of flue gas desulfurization (FGD) system. Fig. 3(b) shows the application rate of FGD by province. In 2005, the capacity of units with FGD was 45 GW, only 13% of the total capacity of coal-fired plants. During 2005–2010, coal-fired power plant is the major source for SO2 control. All the units built after 2004, as well as substantial existing ones, were required to be installed with FGD. The units with FGD would reach 477 GW in 2010, approximately 70% of the total capacity. Southwestern China would be the area with largest application rate of F

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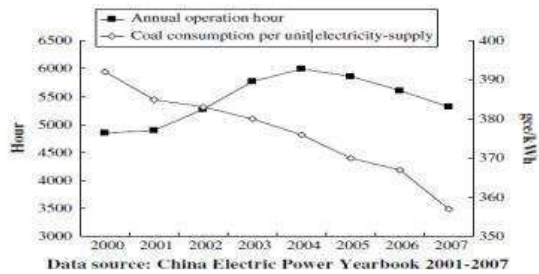
GD, followed by northern China.

Nox emission rates are influenced by different factors, however, previous studies usually applied an average emission rate (8.85 kg NOx emitted per ton coal combusted) due to lack of detailed source information (Hao et al., 2002).In this study, we explored a technology-based method. A database was first established, which contained over 140 emission rates derived from unpublished testing results by Tsinghua University and other domestic measurements (Tian, 2003; Zhu et al., 2004; Bi and Chen, 2004; CRAES, 2006; Yi, 2006a). These emission rates were classified into different sets by fuel quality, boiler type, and emission control level. Emission factors by type were then obtained by averaging the values in corresponding datasets. Table 1 gives the NOx emission factors used in this study, ranging from 4.0 to 11.5 kg t_1.

Emision factors of particulate matters (PM) were estimated mainly based on the model developed by Zhang (2005), in which the unabated emission factors were calculated as a product of the fuel ash content and the ratio of fly ash. The ash content of coal consumed by each region was calculated from the ash content of mining coal and the coal transportation flow matrix by CCTA (2003) and Jian (2004). The national average of ash content in coal was 21.7% in 2005.
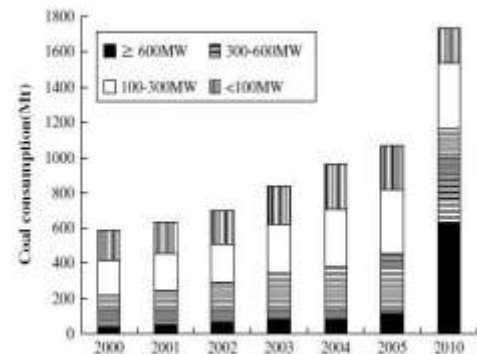
Fig. 2. Coal consumption of power plants by unit size during 2000–2010 [Mt].

The ratio of bottom ash (ar) during the combustion process was determined as 0.20 for pulverized boilers and 0.85 for grate boilers (SEPA, 1996). The percentages of PM10 and PM2.5 in unabated total particulates (TSP), and the removal efficiencies of PM emission control technology, were obtained from a series of domestic measurements (unpublished studies by Tsinghua University; Yi et al., 2006b) as summarized in Tables 2 and 3. Since wet FGD is becoming more and more prevalent, its benefits on PM control should be considered in the emission estimates. Table 3 summarizes recent results and provides the values used in this study. Christo Ananth et al. [4] discussed about Intelligent Sensor Network for Vehicle Maintenance System. Modern automobiles are no longer mere mechanical devices; they are pervasively monitored through various sensor networks & using integrated circuits and microprocessor based design and control techniques while this transformation has driven major advancements in efficiency and safety. In the existing system the stress was given on the safety of the vehicle, modification in the physical structure of the vehicle but the proposed system introduces essential concept in the field of automobile industry. It is an interfacing of the advanced

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technologies like Embedded Systems and the Automobile world. This "Intelligent Sensor Network for Vehicle Maintenance System" is best suitable for vehicle security as well as for vehicle's maintenance. Further it also supports advanced feature of GSM module interfacing. Through this concept in case of any emergency or accident the system will automatically sense and records the different parameters like LPG gas level, Engine Temperature, present speed and etc. so that at the time of investigation this parameters may play important role to find out the possible reasons of the accident. Further, in case of accident & in case of stealing of vehicle GSM module will send SMS to the Police, insurance company as well as to the family members.

Results

Emissions from 2000 to 2005

Emissions of SO_2, NO_x and PM from coal-fired power plants from 2000 to 2005 were calculated using the unitbased activity data and emission factors, as shown in Fig. 4. During 2000–2005, the period when power sector in China developed fastest within the past 20 years, SO_2 emissions increased by 1.5 times, and, notably by 1.8 times in northwestern and 1.6 times in central & southern China. SO_2 emission from coal fired power plants in 2005 was estimated to be 16 097 kt, approximately 53% of the national emissions. As listed in Table 4, five provinces with largest coal consumption, including Shandong, Henan, Hebei, Shanxi, and Jiangsu, emitted over 1000 kt SO_2 each, followed by Guizhou and Sichuan where high-sulfur coal was commonly used. SO_2 emissions of power plants in Beijing,

Hainan, and Qinghai, were less than 100 kt. Emissions from units less than 300MW, which accounted for half of the total capacity, reached 10124 kt, accounting for 63% of the total emissions.

Even faster than SO_2, NO_x emission increased by 1.6 times during 2000–2005. Southwestern and central & southern were the areas with fastest emission increase by 1.9 and 1.7 times respectively. The NO_x emission from coalfired power plants in 2005 was estimated to be 6965 kt, approximately 36% of the total national emissions. Each of Jiangsu, Shandong, and Henan emitted over 500 kt NO_x, while Hainan and Qinghai less than 20 kt. The LNBinstalled units which accounted for 62% of the total capacity and consumed 53% of coal in the power sector, emitted 3255 kt NO_x, 47% of the total emissions. This implied that the emission control effect of LNB was quite poor (less than 30% according to our estimate). Regarding the fuel quality, anthracite would cause higher NO_x emission due to relatively low content of volatile matter compared with bituminous. In 2005, the share of anthracite and lean coals was about 20%, and the units using those coals emitted 2230 kt NO_x, 32% of the total emissions. The primary PM emission increased to 2848 kt by 1.2 times during 2000–2004, and southwestern and northwestern were the areas with fastest increase by 1.4 times. In 2005, the emission by power sector dropped slightly to 2774 kt, less than 10% of the total national emissions. Each of Henan, Jiangsu and Shandong emitted over 200 kt. Emissions of PM10 and PM2.5 were 1842 and 994 kt, respectively. Large discrepancy of size characteristics was

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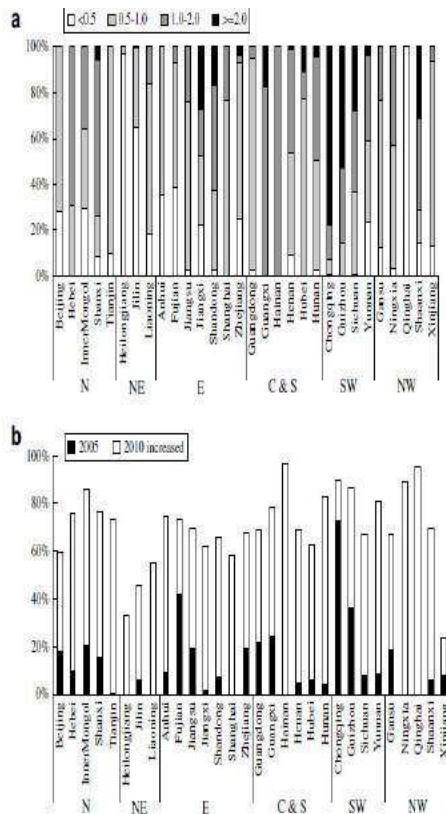
found between pulverized boilers and grate boilers. The ratios of PM2.5 and PM10 to TSP emission from grate boilers were 65% and 89% respectively, much higher than those from pulverized boilers (31% and 63% respectively). The main reason is that wet scrubber and cyclone commonly applied in grate boilers have much lower removal efficiency to fine particles than electrostatic precipitator (ESP) applied in pulverized boilers.

We mainly compared our estimation with other studies for year 2000, as well as other years if applicable. As shown in Fig. 5(a), the SO2 emission from coal-fired power sectors in 2000 has been estimated to be in the range 7500–13330 kt. Our result, 10 950 kt, was higher than most other studies except for EDGAR. In 2005, our estimate was even 15% higher than that estimated by State Environmental Protection

Administration (SEPA). The reason is that 1) the activity level obtained with unit specific method was somewhat higher than the national statistics, which was confirmed by Akimoto et al. (2006) and 2) the sulfur retention used in the official estimation was commonly 0.15, higher than that used in this study. Similar situation was also found for NOx. As shown in Fig. 5(b), the Nox emission range of power sector was estimated to be 2430–5120 kt in 2000, and our result was 4340 kt, lower than

Table 1
NO$_x$ emission factors used in this study (kg t^{-1})

Unit Size	Boiler type	With LNB		Non-LNB	
		Bituminous/lignite	Anthracite/lean coal	Bituminous/lignite	Anthracite/lean coal
>100 MW	Tangentially-fired	4.05	7.80	6.60	10.07
	Swirl Burner	5.46	0.56	7.40	11.46
	W-flame	5.82	11.17	N/A	N/A
<100 MW	Tangentially-fired	N/A	N/A	6.17	9.36
	Swirl burner	N/A	N/A	6.93	10.65

Table 2
Size fraction of unabated particulate matter from coal-fired power plants in China

Unit size (MW)	Boiler type	Fraction			Literature
		>PM$_{10}$	PM$_{2.5-10}$	PM$_{2.5}$	
29	Grate	0.72	0.18	0.1	Unpublished
50	Pulverized	0.64	0.3	0.06	Yi et al., 2006b
50	Pulverized	0.77	0.16	0.07	Unpublished
50	Pulverized	0.80	0.14	0.06	Unpublished
100	Pulverized	0.61	0.37	0.02	Liu et al., 2003
100	Pulverized	0.80	0.13	0.07	Unpublished
125	Pulverized	0.88	0.10	0.02	Unpublished
140	Pulverized	0.91	0.08	0.01	Yi et al., 2006b
165	Pulverized	0.80	0.15	0.05	Unpublished
200	Pulverized	0.84	0.12	0.04	Yi et al., 2006b
200	Pulverized	0.83	0.12	0.05	Unpublished
200	Pulverized	0.85	0.11	0.04	Unpublished
220	Pulverized	0.83	0.15	0.02	Yi et al., 2006b
600	Pulverized	0.82	0.16	0.03	Yi et al., 2006b
600	Pulverized	0.86	0.11	0.03	Yi et al., 2006b
–	Pulverized	0.56	0.28	0.16	Huang et al., 2003
Data used in this study	Pulverized	0.78	0.17	0.05	–
Data used in this study	Grate	0.63	0.23	0.14	Klimont et al., 2002

Emissions in 2010

Although coal consumption during 2005–2010 would sharply increase by 62%, SO2 emissions from coal-fired power plants would decrease to 11801 kt, attributed mainly to the installation of FGD. Emissions from units less than 300MW would keep being a major contributor, accounting for 63% of total emissions. Although each of Shandong, Hebei, and Henan would

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decrease the emission by over 400 kt during 2005 2010, these provinces would still be the largest emission areas in 2010. Meanwhile, there would be small emission increase in some western provinces, like Qinghai, Chongqing and Xinjiang.
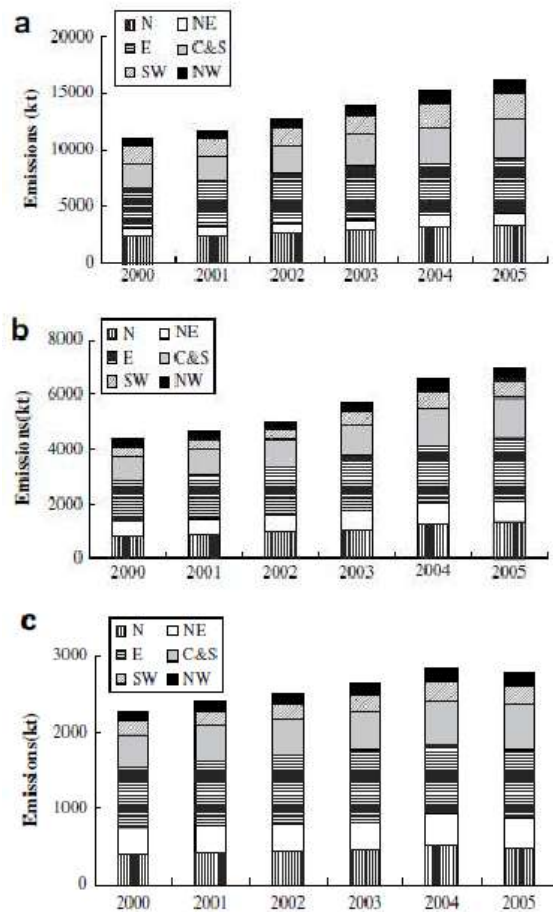
Different from SO2, no further stringent control measures for Nox have been planned except the emission standard amendment in 2003. Advanced technologies such as selective catalyst reduction (SCR) would not be widely used except in Beijing till 2010. Thus NOx emission would keep increasing in the near future and would reach 9680 kt in 2010. The LNB installed units, increasing to 77% of the total capacity, would emit 6380 kt NOx, 66% of the total emissions by power sector. The emissions of Shandong, Henan, Jiangsu and Inner Mongolia would exceed 700 kt. During 2005 2010, Inner Mongolia and Shanxi would have the largest emission increase, i.e. 391 and 221 kt respectively. Shanghai and Beijing, however, would have their NOx emission reduced attributed to the application of SCR.

Although no stricter control policies are planned for PM, the emission in 2010 would decrease to 2540 kt. The main reason for that is the widely installation of wet FGD system, which has similar PM removal efficiency as wet scrubber. However, PM2.5 emission would increase slightly, owing to the poor control effect of FGD to fine particles. The PM emissions of Henan and Zhejiang would exceed 200 kt, while Hebei, Jiangsu and Shandong would reduce their PM emissions by 44, 30 and 21 kt respectively.

Table 3
The removal efficiency of particulate matter from coal-fired power plants in China

Spatial allocation

To better understand the regional distribution of the power emissions, the spatial allocation of emissions based on unit information was made using a 36_ 36 km grid system covering most part of mainland China. The emission of each power

plantwas assigned to corresponding grid cell where the plant was located.

Gridded coal-fired power emissions of SO2, NOx, and PM in 2005 are It can be seen from the figure that eastern region with nearly one-third of total coal-fired power emissions had the highest emission intensity for alln the species, followed by central & southern, northeastern and northern regions. Those areas, which covered only 43% of country territory but contained 78% of national population and 87% of GDP in 2005, accounted for 78%, 84%, and 85% of the national power emissions for SO2, NOx and TSP respectively. The spatial distribution of power emissions implied that power constructions in China were still largely influenced by the population density and economy strength.

Policy analysis of emission control

Closing small units

The emission of small units is a serious problem in China. Due to low combustion efficiency and poor emission control technology, the energy consumption and pollutant emissions of small units were extremely high in recent years. In 2000, the units smaller than 100MWadded up to 56 GW and had a coal consumption of 181 Mt, accounting for 25% of the total unit size and 29% of coal consumed by power sectors. The emission fraction of those small units for SO2, NOx, TSP and PM2.5 reached to 31%, 32%, 55% and 69% respectively. During 2000–2010, along with rapid development of large units and retirement of some small units, the share of NOx, TSP and PM2.5 emissions from units smaller than 100MWwould decrease

gradually to 16%, 41% and 49% respectively. Since FGD system would be applied with most large power units, the SO2 emission share of small units would increase to 33%. Compared with unit size and energy share (9.0% and 11.2% respectively in 2010), the emission of small units would still be very high

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Facing this huge challenge, more stringent regulations for small units are, or will be, taking effect. According to latest policy, the units smaller than 50MW, and the units smaller than 100MW with a working period more than 20 years, should be pushed to close gradually in near future. Moreover, all the new-built condensing steam units should be larger than 300MW. If all the units below 25MW(most are grate boilers) were shut down by 2010, approximately 2173, 622, and 540 kt emission abatement of SO2, NOx, and TSP would be achieved, and the emission share of units smaller than 100MW would be further reduced to 17%, 8%, and 22% respectively, implying the significant benefits of closing small units.

Emission control in acid rain and SO2 control zones

Since 1998, approximately 11.4% of national territory have been designated as the acid rain control zones and SO2 pollution control zones (Two-Control Zones for short) to protect those areas which were, or might be, affected by acid deposition or ambient SO2 pollution (Hao et al., 2000). The total capacity in the Two-Control Zones in 2000 was 138 GW, and it would increase to 313 GW by 2010. In this study, SO2 emissions from coal-fired power plants in the Two Control Zones in 2000, 2005 and

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2010 were estimated to be 6981, 9472 and 6659 kt, approximately 64%, 61% and 56% of the national emissions respectively, without satisfying abatement.

According to the Two-Control Zones regulation, all the power units in the zones should be installed with FGD systems till 2010 if sulfur content of coal consumed is higher than 1.0%. In fact, however, this policy has not been implemented strictly. In 2010, the capacity of units with sulfur content higher than 1.0% would still be 33 Gwin the Two-Control Zones. If these units could be also installed with wet FGD by 2010, approximately 1671 kt SO2 and 100 kt TSP emissions would be further reduced, and the SO2 emission share from power units in the Two-Control Zones would sharply decrease to 49%, implying that there are still considerable potentials for SO2 emission reduction for power plants in Two-Control Zones. Taking both closing small units and control policies in Two-Control Zones into account, the SO2, NOx and TSP emissions of national coal-fired power sector in 2010 would be further reduced by 33%, 6% and 25% respectively compared to the results described in Section 3.2.

Future projection

Several studies predicted Chinese emissions based on their future energy consumption estimation (Streets and Waldhoff, 2000; Klimont et al., 2001; Ohara et al., 2007). Choosing 1995 or 2000 as the base year, however, those studies generally did not expect the tremendous increase in fuel consumption during 2000–2005, and the forecasted energy level (including coal consumption by power sector) was commonly underestimated. In this study, both coal consumption and emission control strategies of power sectors during 2010–2020 were evaluated through scenario analysis for future emission projection.

Energy consumption
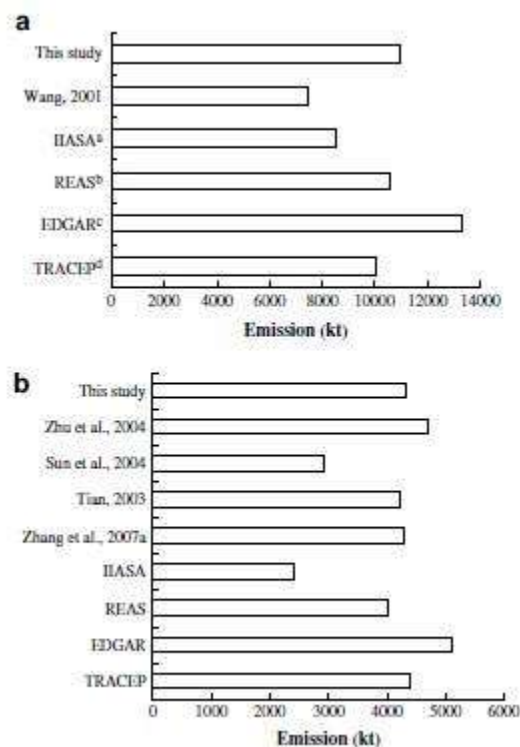
The future electricity demand and coal consumption were estimated through the elasticity of electricity, the ratio of electricity growth rate to GDP growth rate. During 2000–2005, the national elasticity of electricity increased dramatically along with the fast conomy growth and development of high-energy consumed industries. Though
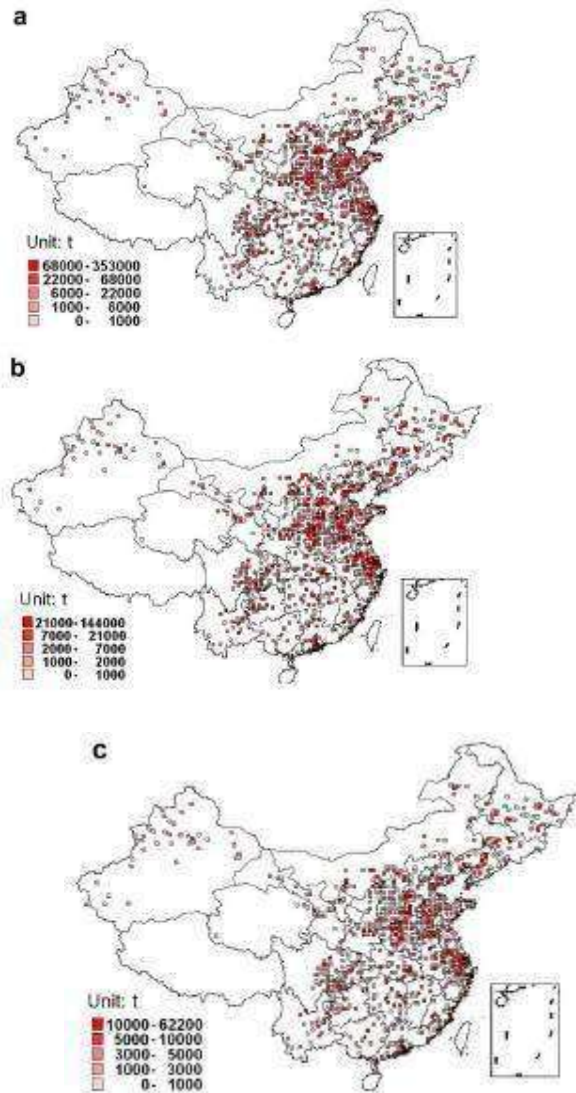
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dropped slightly after 2005, it still kept higher than 1.20. It was believed that the electricity growth rate would become less than GDP growth after 2010, and the elasticity of electricity would thus decrease below 1.0, owing to adjustment of industry structure and implementation of energy saving (NDRC, 2004; SPERI, 2007).

In this study, high (H), medium (M) and low (L) energy scenarios were assumed. As listed in Table 5, elasticity of electricity and macro economy data taken from NDRC (2004) and Wu (2007) were adjusted according to latest national energy plan (SPERI, 2007) and applied in the projection. The H scenario describes a picture of relativelyrapid economy and electricity growth, and a coal-dominated energy structure inwhich the coal-fired electricity would still account for more than 70% in power sector. The M scenario describes a picture with the same economy and electricity growth as H, but with changes in energy structure, in which considerable switch to clean fuels, such as natural gas and hydro power, would be achieved in power sector. The L scenario describes a scenario with the same energy structure as M, but a slower economic and electricity growth, emphasizing more on sustainable development. Under the scenarios, the development of coal-fired power sector during 2010–2020 would slow down compared with that during 2000–2010. The coal consumption in 2020 was estimated to reach 2769, 2510, and 2176 Mt in H, M and L respectively. The obtained results were compared with those by IEA (2007). IEA provided two energy scenarios, the Reference (REF) scenario as the usual scenario and the Policy Alternative (POLICY) scenario in which policies of energy saving and energy structure adjustment would be implemented. The unit

capacity estimated in this study was higher than `11`1` IEA, but the coal consumptions were very close between the M scenario in this study and REF scenario by IEA, in which a more conservative coal consumption rate (355– 360 gce kWh_1 in 2015) was used.

Emission control policy

After 2010, coal-fired power sector would still be an important emission control source. FGD would be doubtless widely applied as it is since 2005. Moreover, the

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application rate of SCR and filter fabric (FF) would also rise though with an uncertain rate. In this study, base (1), normal (2) and strict scenarios (3) were designed to describe different emission control policies. Base scenario is a pessimistic one in which the emission control for all

applicable for the coal-fired power sector in the future. The projected application rate of different emission control technologies is summarized in

Emission forecast

Owing to relatively slow increase of energy consumption and implementation of emission control policy, the emissions of coal-fired sectors would be futher restrained after 2010. Fig. 8 shows the emission projection of coalfired power plants under all the possible scenarios.

the species would remain at the current stage, without any further measures to cut emissions of existing units. FGD, LNB and ESP would be required for all the new-built units compulsorily. The normal scenario emphasizes the implementation of closing and substitution of small old units. Grate boilers with wet scrubber and cyclone dust collectors would be replaced with large units with high combustion efficiency and advanced emission control technologies. During 2015–2020, SCR technology and FF would be gradually installed on new-built units. Based on the normal one, the strict scenario is an optimistic one, which stressed most on emission abatement. FGD would be installed on all the existing units using high-sulfur coals in the Two-Control Zones. SCR and FF would be largely applied since 2010. According to national policy on energy saving and emission control, we mean the normal scenario would be the most
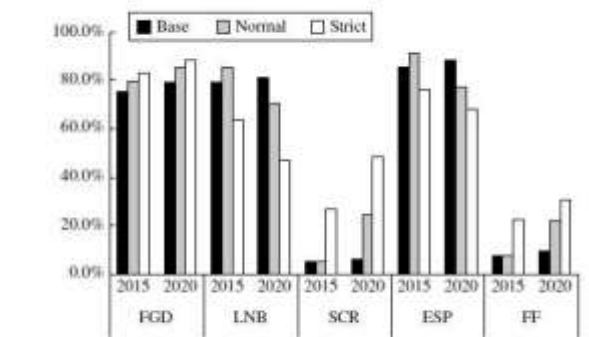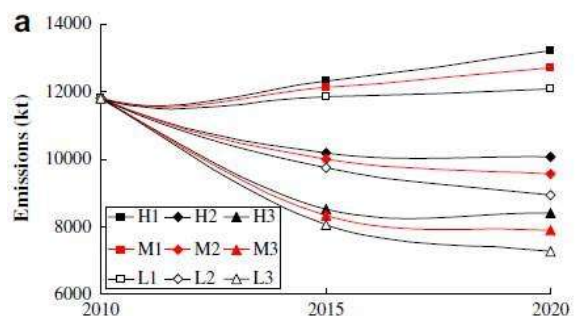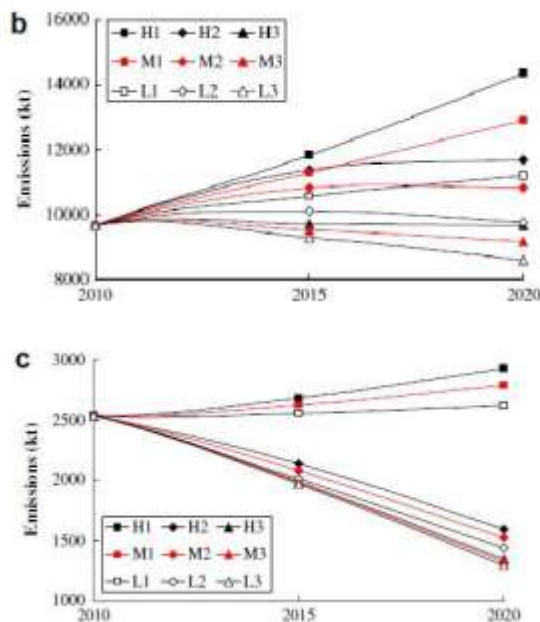

g. 7. The application rate of emission control technologies in 2015 and

The estimation under M2 would be the 'best guess'' of future emissions, while other scenarios could be consulted for the uncertainty caused by different levels on coal consumption or emission control.

During 2010–2020, the SO2 emission would increase monly under base control scenario (L1, M1 and H1) by 2 12%, and it would decrease by 15–24% and 29–38% respectively under normal (L2, M2 and H2) and strict control scenarios (L3, M3 and H3). Under M2, the emission in 2020 is estimated to be 9560 kt, and it would vary between the range 7889–12 702 kt under medium coal consumption scenarios with different control stages (M1, M2 and M3), and the much smaller range 8941 10 077 kt under normal control scenarios with different coal consumption levels (L2, M2 and H2). This result implied that the implementation of control policies would have a more significant influence on SO2 emission than the activity levels

. Similarly, and even more obvious trends can also be found for PM emissions. The PM emissions from coal fired power sector would increase by 3 15% under base control scenarios during 2010 2020.

However, it would decrease by 37–43% under normal control scenarios, indicating the great benefits of closing small units and grate boilers. Under M2, the emission in 2015 and 2020 was estimated to be 2083 and 1528 kt respectively, approximately 79% and 54% of the emissions under M1 in corresponding years. Under strict scenarios, the emission in 2015 and 2020 would reach 1969–1989 and 1296–1347 kt respectively, without significant abatement compared with normal control scenarios

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The situation for NOx is a bit different. The emission during 2010 2015 would increase under all the scenarios except the ones with strict control policies at medium and low activity levels (M3 and L3). During 2015–2020, the emissions under all the strict control scenarios (L3, M3 and H3), and the normal control scenario with lowactivity levels (L2) would decrease along with the application of SCR. However, the emission under all the scenarios except M3 and L3 would still be higher than that in 2010.Under M2, the NOx emission in 2015 and 2020 would keep constant at around 10 835 kt, higher than the SO2 emission of 10 000 and 9560 kt respectively. This result indicated that the Nox emission from power plants would become a more serious problem. Moreover, the effect of control policies and activity levels on NOx emission is more complicated than SO2 and TSP, implying thatNOx emission control needs an even more comprehensive consideration in the future.

In conclusion, the SO2 and PM emissions of power sector could be effectively controlled with the measures of closing small units and the wide application of FGD and high-efficiency dust collectors. Thus those control policies should be

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followed through in the future. However, NOx emission of power sectorwould probably increase along with the energy consumption growth, and become a new challenge for Chinese air pollution control. Therefore newpolicy should be planned for NOx emission abatement as soon as possible

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