Supporting Information (SI) for

Current emissions and future mitigation pathways of coal-fired power plants in China from 2010 to 2030

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Text S1. Unit-based power plant emission inventory from 2010-2015

MEE database provides unit-based information with high quality, not only for basic unit information, but also yearly emission-related parameters. It contains unit-based installed capacity, the operational status of the unit (when the unit was commissioned/decommissioned), geo-locations, combustion technology, coal type, coal quality (e.g. heating value, sulfur content, and ash content), annual coal consumption, annual coal-fired power generation, the operational status of the abatement equipment and corresponding removal efficiencies. The application of each parameter from MEE database when estimating air pollutants and CO_2 emissions is fully detailed below.

Activity rates

Activity data of each unit are available for the period of 2010-2015 from MEE database, including the operational status (when the unit was commissioned/decommissioned), the heating value of the coal (H), the annual coal use, and the power generation. Here we derive the coal consumption rate (P) and the annual operating hours (T) without the direct application of annual coal use and the total power generation in order to eliminate the abnormal values by checking the historical unit-based information from the CPED. In addition, we checked the unit-based data before our calculation. And the sum-up of unit-based activity rates from MEE database are well matched with the provincial data from energy yearbook[1]. The monthly fraction of annual electricity generation (f) is quantified by province considering the data availability, which is derived from the statistics[2] with adjustments for units commissioned or decommissioned within that year by normalizing those operating months.

In addition, for the units newly built during 2010 and 2015, the coordinates of each units (latitude and longitude) were obtained from MEE database and then validated one-by-one all these units to ensure their accurate geo-locations, the cross-check process shows that the originally recorded coordinates in MEE database are essentially accurate.

Emission factors

The equation for calculating SO_2, $PM_{2.5}$, PM_{10} and CO_2 emission factors could been found in our previous paper[3].

SO_2. The unabated SO_2 emission factors were determined by the sulfur content of coal and the fraction of sulfur retention in ash. The sulfur content for each unit from 2010 to 2015 was obtained from MEE database. The average sulfur content stays stable from 2010 to 2015 (0.95%, as shown in Table 1). The fraction of sulfur retention in ash was assumed to be 15% for all the units.

Our previous study has shown the wide installation of FGD systems in China's coal-fired power plants since 2005[3]. The operating conditions and actual SO_2 removal efficiencies of FGD for each unit from 2010 to 2015 were obtained from MEE database. Post combustion FGD techniques can remove SO_2 formed during combustion by using an alkaline reagent to absorb SO_2 in the flue gas[4]. MEE database shows there are currently three main types of FGD systems equipped in coal-fired power units: wet FGD, semi-dry FGD, and dry FGD. In general, wet FGD systems have higher average removal efficiency compared to semi-dry FGD and dry FGD systems, which could achieve removal efficiencies as high as ≥95%[4]. To date, wet FGD systems have been widely installed in coal-fired power units to meet the stringent emission standards. In fact, the removal efficiency of the abatement equipment for each unit depends on their operational conditions. Due to the burden of air quality improvement, the FGD facilities are continuously installed in coal-fired power units, and the coal-consumption weighted mean SO_2 removal efficiencies of all FGD facilities is further improved from 78.0% in 2010 to 88.6% in 2015 (see Table 1). In this study, we assumed that the removal efficiency of wet scrubbers for SO_2 is 20% to stay consistent with our previous work[3].

NO_x. The unabated NO_x emission factors are from CPED for different boiler size, combustion technology, and coal type. The operating conditions and actual NO_x removal efficiencies for each unit were obtained from MEE database. Several techniques are used to reduce NO_x emissions from coal combustion in coal-fired power plants. There are two types of de-NO_x controls: combustion controls (e.g., low-NO_x burner technology) and post-combustion controls (e.g., selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR))[4, 5]. Combustion controls reduce

NO_x by suppressing NO_x formation during the combustion process, while post-combustion controls reduce NO_x emission after their formation. NO_x emissions were regulated in China's coal-fired power plants since 2011, and the coal-consumption weighted mean NO_x removal efficiency is greatly improved to 62.0% in 2015 (Table 1), which is the most important step to reduce national NO_x emission by 10% during the 12th Five-Year Plan.

PM. PM emission were estimated for two size fractions: $PM_{2.5}$ and $PM_{2.5\text{-}10}$ (PM with diameter more than 2.5 μm but less than 10 μm, coarse particles). The unabated emission factors of $PM_{2.5}$ and PM_{10} were determined by the ash content of coal, the mass fraction of retention ash, and the mass fractions of $PM_{2.5}$ and $PM_{2.5\text{-}10}$. The ash content of coal for each unit in 2010 was applied to every year due to lack latest data. The fraction of retention ash and the mass fractions of $PM_{2.5}$ and $PM_{2.5\text{-}10}$ are derived from CPED[3]. There are mainly four types of technologies used in coal-fired power plants as post-combustion methods to remove PM emissions at present: cyclones (CYC), wet scrubbers (WET), electrostatic precipitators (ESP), and fabric baghouse (FAB). The technology type for each unit was obtained from MEE database. Statistic shows that ESP and FAB are the two main technologies applied in coal-fired power plants during 2010-2015 (see Table 1), and ESP and FAB gradually replace low-efficiency control technologies (e.g. CYC and WET). The average removal efficiencies of each technology for $PM_{2.5}$ and $PM_{2.5\text{-}10}$ emissions were obtained from previous study[3, 6, 7], as shown in Table S5. Note that although PM emissions could be significantly reduced by dust precipitators, most of the fly ash particles are collected and transformed to waste residue.

CO_2. The emission factors for CO_2 was calculated following the guidelines from the Intergovernmental Panel on Climate Change (IPCC)[8]. Until 2015, no control measures were implemented to remove CO_2.

Text S2. Future projections

Estimation of future coal-fired electricity demand

Table S2 summarized the estimates of coal-fired power generation penetrations in 2030 from various reports[9-13]. For comparing and analyzing the influence of coal-fired power generation demand on air pollutant and CO_2 emissions, two coal-fired power generation demand scenarios are designed in this work.

"Development forecast of medium and long-term power generation capacity and power generation demand in China" projected the share of fossil-fuel-fired power capacity ranges from 50-60% by 2030[14]. And "Development forecast of renewable energy power generation in China during 13th Five-Year-Plan" projected the share of renewable power generation should be up to 27% by the end of 2020[15]. Meanwhile, we refer to the designed scenarios by previous study and moderate energy scenarios provided by International Energy Agency[12] and U.S. Energy Information Administration[13] (Table S2). The coal-fired power generation shares of 57% is chosen as the current development planning. In view that the share of coal-fired power generation is 70.8% by 2015 and a decrease to 57.0% in 2030 is designed as one scenario, a more aggressive policy is considered to represent the vigorous expansion of renewable power generation under stringent climate targets. As Table S2 summarized, there are eight scenarios projecting lower shares of coal-fired power generation (≤ 57%) in 2030. An average share of 43% is chosen as the other scenario for comparison.

In addition, although the total of installed capacity with planned CCS technology are pretty small compared to current total operating capacity (~0.7%), a large range of coal-CCS penetrations in 2030 is projected under various public scenarios[9-13], which ranges from 0.0% to 12.5% as considering different climate targets (Table S2). Although CCS technology could reduce the CO_2 emissions, additional electricity demand would increase the energy consumption and corresponding air pollutant and CO_2 emissions. It is reported that an additional 25-40% energy would be consumed when operating CCS systems[16], which has a big impact on the electricity demand as CCS systems are widely placed into commercial use in the future. In this work, 10% of coal-CCS power penetration by 2030 and additional 40% energy consumed are considered as a set of sensitivity test scenarios to quantify the trade-off between air pollutants and CO_2 emissions. Table S3 summarized the estimates of coal-fired power generation demand under sensitivity test scenarios during 2015-2030. In addition, the CO_2 removal efficiency of CCS technology can be up to 85-90%[16]. The removal efficiency of 90% for CCS technology is adopted in this work.

Similarly, electricity energy is to be consumed so as to make conventional end-of-pipe control measures operate[17-20]. Abatement measures for controlling SO_2, NO_x and PM emissions are mandatorily required in coal-fired power units[21]. Although end-of-pipe control measures could significantly reduce emissions, which also have an opposite influence on air pollutant and CO_2 emissions by increasing energy consumption. De-SO_2, de-NO_x, and de-PM devices usually take up 1.1-1.5%, 0.2-0.6% and 0.3-0.6% of the whole power plant's electricity energy consumption[17-20], respectively. Meanwhile, the energy consumptions of these end-of-pipe control measures gradually decrease through energy-saving retrofits. In this work, 2% of additional energy consumption for each unit is considered to quantify their impacts on air pollutant and CO_2 emissions (Table S3). A sets of sensitivity test scenarios (CHER-BAT, CLER-BAT scenarios) are designed to quantify the impacts of additional energy consumptions by control measures on air pollutant and CO_2 emissions.

Modeling future power plant fleet

Under two power supply scenarios, the power supply gap was filled up by new generation units. Based on an issued policy called the "new generation units with installed capacity ≥ 600 MW in principle"[22], we assumed that newly built units will be dominated by large units (≥ 600 MW). Ultra-supercritical (USC) units and integrated gasification-combined cycle (IGCC) units are expected to be widely promoted in the near future[23]. We assumed the penetration rates of USC and IGCC technologies in new capacity change from 50% and 10% in 2016 to 70% and 30% in 2030[23, 24], respectively. Employing those assumptions, we simulated the year-to-year dynamics of power plant fleet turnover by the capacity size and combustion technology. In addition, locating new power plants is complicated[25, 26] with high uncertainty because of electricity transmission across power grids and future plans[27, 28]. Therefore, the new capacity demand is estimated by province, and then aggregate into the whole China for the analysis.

Under the ER scenario, we extensively investigated the main factors governing the lifespans of all the operating units in China by analyzing all the retired units from the CPED, meanwhile referenced the Power Plan. In most cases, old, small, or low-efficiency coal-fired units would be retired early (Figure S1). Our study modeled the historical survival of all the generators by considering their ages, installed capacities, and coal consumption rates. And we then predicted the survival curves of in-fleet units and determined their retirement orders by their median retirement ages.

Proportional hazards regression (also called Cox regression) was used in this study to model lifetime of in-fleet operating units. The function is shown below:

$$[\mathrm{b}, \mathrm{logl}, \mathrm{H}, \mathrm{stats}] = \mathrm{coxphfit}([\mathrm{Var}_{\mathrm{cap}}\ \mathrm{Var}_{\mathrm{corat}}], \mathrm{age}, '\mathrm{censoring}', \mathrm{censor})$$

where b represents coefficient estimates, logl represents log likelihood, H represents estimated baseline cumulative hazard; stats represents coefficient statistics. $\mathrm{coxphfit}$ represents cox proportional hazards regression, censoring indicator for censoring $\mathrm{Var}_{\mathrm{cap}}$ and $\mathrm{Var}_{\mathrm{corat}}$ represent installed capacity and coal consumption rate of coal-fired power units, age represents lifetimes for the retired units and operated years (the year of 2015 minus the online year for each unit) for the in-fleet units. $Censoring$ is the indicator for censoring by using 1 for the in-fleet units and 0 for the retired units. All the operating and retired units (totally 7,814 samples) in CPED are brought into this model as the training data when developing this function, and R-squared (R^2) are used in the Cox's proportional hazards model to assess the goodness of fit tests. The results show the R^2 value is 0.73 in this model, and the function analog effect is good. We thus predict the survival curve of in-fleet units and determine their retirement order by their median age of retirements.

Besides, retirement rate also affects the future power plant fleet and emission trends. Statistics from CPED shows China has phased out small, old, or low-efficiency units with the total installed capacity more than 90 GW in the past decade. Driven by the stricter phase-out strategy than before, our calculation indicates nearly 400 GW of total capacity is more likely to be identified as the phase-out target until 2030 (Figure S2). We thus assumed that 40% of national total capacity would be retired early before 2030 in the ER scenario. The power supply gap from the early-retired units was completely filled by new generation units.

Modeling the future power plant fleet has provided an overall understanding of changes in the power supply structure. The coal consumption of all units was further estimated by multiplying the power generation by the coal consumption rates. The coal consumption rates of in-fleet units were obtained from the CPED, and the coal consumption rates of new generation units were estimated for the combustion technologies (Table S1). Notably, our model begins with the same coal-fired electricity demand and estimates coal consumption at the unit level under various power supply scenarios to explore future energy-saving pathways.

Evolution of end-of-pipe control technologies

We modeled the changes in unit-based emission factors by considering the evolution of the end-of-pipe control technologies. CPED shows ~97% and ~87% of the total installed capacity had been equipped with efficient FGD and selective catalytic reduction (SCR) (and/or selective noncatalytic reduction (SNCR)) technologies by 2015[29], respectively. Although control measures for reducing SO_2 and NO_x emissions are widely applied in coal-fired power plants, most of them operate under poor conditions, and the average removal efficiencies are far below the best removal efficiencies[3, 4, 30]. In addition, over 80% of the total capacity in 2015 was achieved using electrostatic precipitators (ESPs), which have relatively lower removal efficiencies than fabric baghouses (FABs)[6, 7]. Therefore, units with low-efficiency control measures as well as those without control measures must be upgraded using advanced control measures to meet the compulsory standards in China.

Under BAT scenario, we developed a logistic regression model to determine the upgrade order of de-SO_2, de-NO_x, and de-PM devices by considering the power unit lifespan, device online year (year abatement equipment began operating), installed capacity and removal efficiency of each in-fleet unit. Historical data indicate that large and young units are usually upgraded first (Figure S3); note that units without control measures are our priority in our assumptions. The function is shown below:

$$b_s = \text{glmfit}([\text{Var}_{\text{age}} \text{Var}_{\text{cap}} \text{Var}_{\text{eff}}\ \text{Var}_{\text{lifesp}}], \text{recon}, \text{distr})$$

Where b_s represents the coefficient estimates for each speciess, glmfit represents generalized linear model regression (GLM), Var_{age}, Var_{cap}, Var_{eff}, and $\text{Var}_{\text{lifesp}}$ represent the predictor variable values of operating age of corresponding devices, installed capacity of unit, removal efficiency of device, modeled lifespan of unit. recon represent the responses of the generalized linear regression, and distr represents the distribution by 'binomial'. The reason why we choose the GLM is that there is more flexibility in modeling than traditional regression, and GLM models are fitted via maximum likelihood estimation, which is fitted our situation in this work[31, 32]. All the operating units installed de-SO_2 devices, de-NO_x devices, and de-PM devices (totally 4984 samples, 2785 samples, 6046 samples) in CPED are brought into this model as the training data to respectively develop each regression function. The results show the R^2 values are 0.80, 0.70, 0.80 in regression models of upgrading de-SO_2, de-NO_x, and de-PM, respectively. And the function analog effects are good. And we then obtained the corresponding coefficients and scored the in-fleet units to determine the reconstruction order of their de-SO_2, de-NO_x, and de-PM devices. Note that the regression model of upgrading de-PM devices is also applied to BAU scenarios due that only de-PM devices would be upgrade under our assumptions. Based on the total capacity to be upgraded during 2016-2030, yearly targets of upgraded capacity were set under the BAT scenario, and the number of units to be upgraded in order was determined by capacity size.

The unabated emission factors of SO_2, NO_x, $PM_{2.5}$ and CO_2 were assumed to remain constant over time for current units. The NO_x emission factors for new power units were obtained from the CPED for different boiler sizes and combustion technologies[3]. The provincial average emission factors from the CPED were adopted for the SO_2, $PM_{2.5}$, and CO_2 emission factors of new power units.

Emission mitigation pathways

In this study, emissions projections are produced by modelling future power plant fleet and evolution of control technologies. Such projections of changes in policies and technologies are, however, subject to considerable uncertainty under each parametric process. Here we used scenario analysis (developing 'plausible' scenarios that span an interesting range of possible outcomes) to approach the problem of pathways[33]. In our projections model, we identified parameters related to designed policies in modules of power fleet turnover and evolution of end-of-pipe control technologies. We constructed the uncertainty distributions for parameters through expert elicitation or from literatures[3, 34]. With these parameters and their uncertainty distributions, for each scenario, the possible emissions mitigation pathways are explored according a set of runs (100 runs in this study) in the future projections model. The detailed description of the related parameters and their possible distributions is shown in Table S4.

Table S1 Definitions and parameters of the scenarios under each fixed coal-fired power generation demand (High demand and Low demand) in this study.

Power plant fleet turnover scenarios			End-of-pipe control scenarios		
Related parameters	**Natural retirement (NR)**	**Early retirement (ER)**	**Related parameters**	**Business-as-usual (BAU)**	**Best-available-technology (BAT)**
Retirement rate of current capacity	40-year lifetime	40% of total current installed capacity	Removal efficiency of de-SO_2 devices for current units	remain at the same level as 2015	≥ 95%*
Retirement order of current units	/	survival curves	Removal efficiency of de-SO_2 devices for new-built units	89% (remain at the average level as 2015)	95%
Annual operating hours	the same level as in 2015		Removal efficiency of de-NO_x devices for current units	remain at the same level as 2015	≥ 85%*
Combustion technologies of new-built capacity in each year	IGCC: from 10% in 2016 to 30% in 2030; USC: from 50% in 2016 to 70% in 2030; Supercritical (SC): from 40% in 2016 to 0% in 2030. (Linear interpolation for other years)		Removal efficiency of de-NO_x devices for new-built units	62% (remain at the average level as 2015)	85%
Coal consumption rate	IGCC: 290 gce kWh^{-1} USC: 290 gce kWh^{-1} SC: 315 gce kWh^{-1}		Upgraded de-PM devices	at least ESP	combined FAB and WESP**

Sizes of new-built units	600 MW and 1000 MW	Installation or upgrade order of current units	generalized linear model regression for de-PM devices	generalized linear model regression

* The installation and upgrading of current units is assumed to occur before 2020 in Beijing-Tianjin-Hebei (BTH), Yellow River Delta (YRD), and Pearl River Delta (PRD), and before 2030 in other regions in China.

** Upgrade of de-PM devices in the BTH, YRD and PRD regions are assumed to complete for 100% of the total installed capacity before 2020. Upgrade of de-PM devices in other regions are assumed to complete for 80% of the total installed capacity before 2020, and complete for 100% before 2030.

Table S2 Summary of shares of coal-fired electricity demand in 2030 under different scenarios.

No.	Scenarios	Coal-fired electricity generation (TWh)	Share of coal-fired generation (%)*	Share of coal-CCS generation (%)	Coal-CCS/coal-fired generation	References	Note
1	Base scenario	5893	72%	0%	0%	China's Low Carbon Development Pathways by 2050	
2	Low Carbon	3438	48%	0%	0%	China's Low Carbon Development Pathways by 2050	
3	Enhanced Low Carbon	2876	43%	0%	0%	China's Low Carbon Development Pathways by 2050	
4	BAU	/	60%	1%	1%	Gang He et al. (2016)	Estimated by installed capacity
5	BAU with Carbon Cap	/	43%	2%	6%	Gang He et al. (2016)	Estimated by installed capacity
6	Low Cost Renewables	/	44%	1%	1%	Gang He et al. (2016)	Estimated by installed capacity
7	IPCC target	/	42%	9%	22%	Gang He et al. (2016)	Estimated by installed capacity
8	RCP4.5	4564	59%	2%	3%	GCAM model	
9	GCAM8.5	6946	85%	0%	0%	GCAM model	
10	GCAM4.5	4826	63%	1%	1%	GCAM model	
11	GCAMReference	4909	64%	0%	0%	GCAM model	

12	GCAM2.6	4087	49%	13%	26%	GCAM model
13	New Policies scenario	4462	51%	0%	0%	World Energy Outlook 2016
14	Current Policies	5767	61%	0%	0%	World Energy Outlook 2016
15	450 Scenarios	2606	33%	0%	0%	World Energy Outlook 2016
16	/	4500	57%	0%	0%	International Energy Outlook 2017

*Share of coal-fired electricity demand includes coal-fired electricity demand installed CCS systems.

Table S3 The estimates of coal-fired electricity demand during 2015-2030 in this work.

Cases	**Scenarios**	**Year**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Scenarios	/	Total electricity generation (TWh)	5815	5980	6145	6310	6475	6640	6878	7116	7354	7592	7830	8068	8306	8544	8782	9020
	High demand	Share of coal-fired generation (%)	71%	70%	69%	69%	68%	67%	66%	65%	64%	63%	62%	61%	60%	59%	58%	57%
		Coal-fired electricity generation (TWh)	4114	4186	4255	4322	4387	4449	4539	4625	4707	4783	4855	4922	4984	5041	5094	5142
	Low demand	Share of coal-fired generation (%)	71%	69%	67%	66%	64%	63%	61%	59%	57%	55%	53%	51%	49%	47%	45%	43%
		Coal-fired electricity generation (TWh)	4114	4120	4139	4152	4160	4183	4196	4198	4192	4176	4150	4115	4070	4016	3952	3879
Sensitivity test-	/	Share of plant's	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%

conventional control measures		electricity consumption																
	High demand	Coal-fired electricity generation (TWh)	4196	4270	4341	4409	4475	4538	4630	4718	4801	4879	4952	5020	5083	5142	5196	5244
	Low demand	Coal-fired electricity generation (TWh)	4196	4203	4221	4235	4243	4267	4279	4282	4276	4259	4233	4197	4151	4096	4031	3956
Sensitivity test-CCS technology	/	Share of coal-CCS generation (%)	0%	0%	0%	0%	0%	1%	2%	3%	3%	4%	5%	6%	7%	8%	9%	10%
		Share of plant's electricity consumption	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%
	High demand	Coal-fired electricity generation (TWh)	4114	4186	4255	4322	4387	4467	4584	4698	4809	4917	5022	5124	5223	5319	5412	5502
	Low demand	Coal-fired electricity generation (TWh)	4114	4120	4139	4152	4160	4202	4240	4271	4294	4310	4318	4317	4310	4294	4271	4240

Table S4 The related parameters and their uncertainty ranges.

module	Sub category	Parameters and values	Distribution
Power plant fleet turnover	Lifespans of the in-fleet units in natural retirement scenario	40	Normal (CV: 10%)
	Retirement rate of current capacity in early retirement scenario	40%	Normal (CV: 10%)
	Combustion technologies of new-built capacity	IGCC : 10% (2016); 30% (2030)	Normal (CV: 10%)
		USC: 50% (2016); 70% (2030)	Normal (CV: 10%)
		IGCC: 290 gce kWh^{-1}	Normal (CV: 5%)
		USC: 290 gce kWh^{-1}	Normal (CV: 5%)
		SC: 315 gce kWh^{-1}	Normal (CV: 5%)
Evolution of end-of-pipe control technologies	Removal efficiency of de-SO_2, de-NO_x, and de-PM devices	eff_{SO_2}:89% in BAU 95% in BAT	Normal (CV: 5%)
		eff_{NO_x}: 62% in BAU 85% in BAT	Normal (CV: 10%)
		$eff_{PM_{2.5}}$: CYC: 10% (5%-15%) WET: 50% (38%-72%) ESP: 93% (92%-94%) FAB: 99% (98.7%-99.4%) WESP: 99.3% (98.9%-99.6%)	Triangular

	$eff_{PM_{2.5-10}}$: CYC: 70% (65%-73%) WET: 90% (83%-95%) ESP: 98% (97%-99%) FAB: 99.5% (99.3%-99.7%) WESP: 99.6% (98.4%-99.8%)	Triangular

Table S5 Removal efficiencies of different control technologies for particulate matter; values are given as percentages (%).

Technology	$PM_{2.5}$	$PM_{2.5-10}$
Cyclones (CYC)	10	70
Wet scrubbers (WET)	50	90
Electrostatic precipitators (ESP)	93	98
Bag filters (FAB)	99	99.5
Wet electrostatic precipitators (WESP)	99.3	99.6

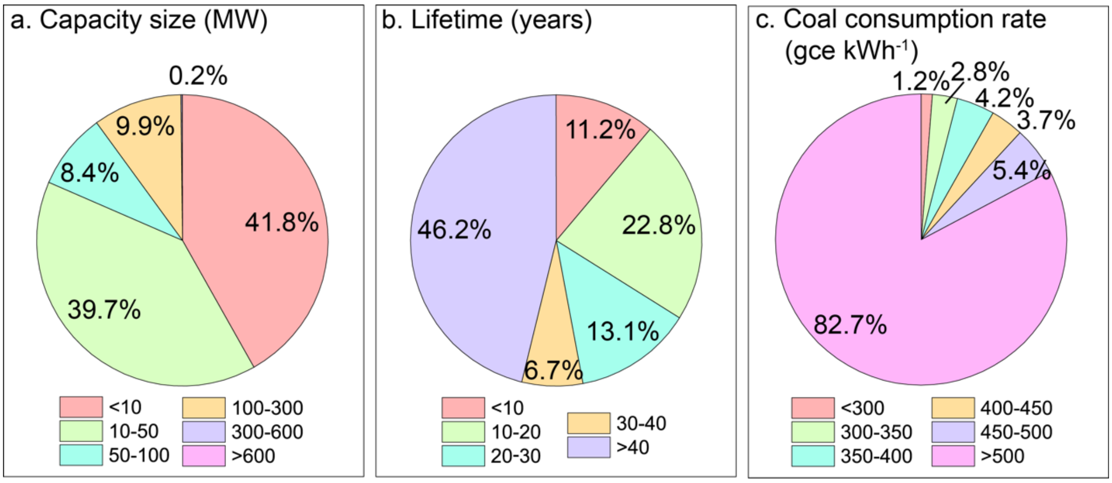

Figure S1. Summary of retired units during 2005-2015 from CPED: (a) by installed capacity; (b) by lifetime; (c) by coal consumption rate.

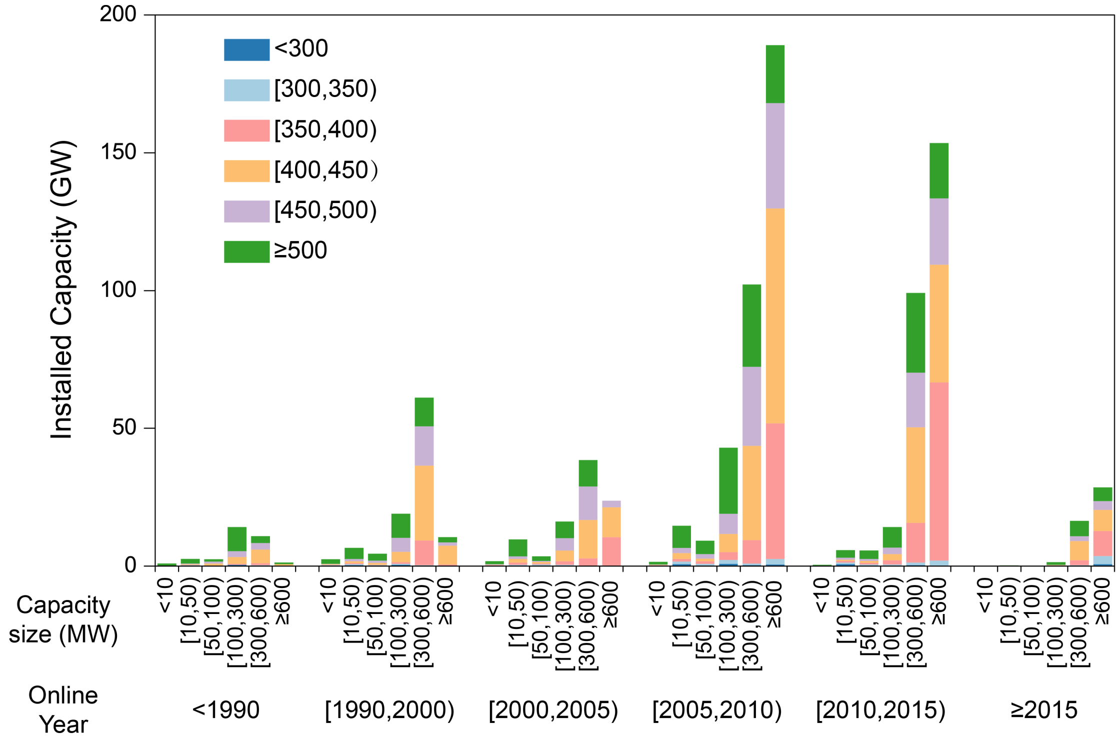

Figure S2. Summary of installed capacity with different coal consumption rates (unit: gce kWh^{-1}) for in-fleet power units by capacity size and online year in the year of 2015.

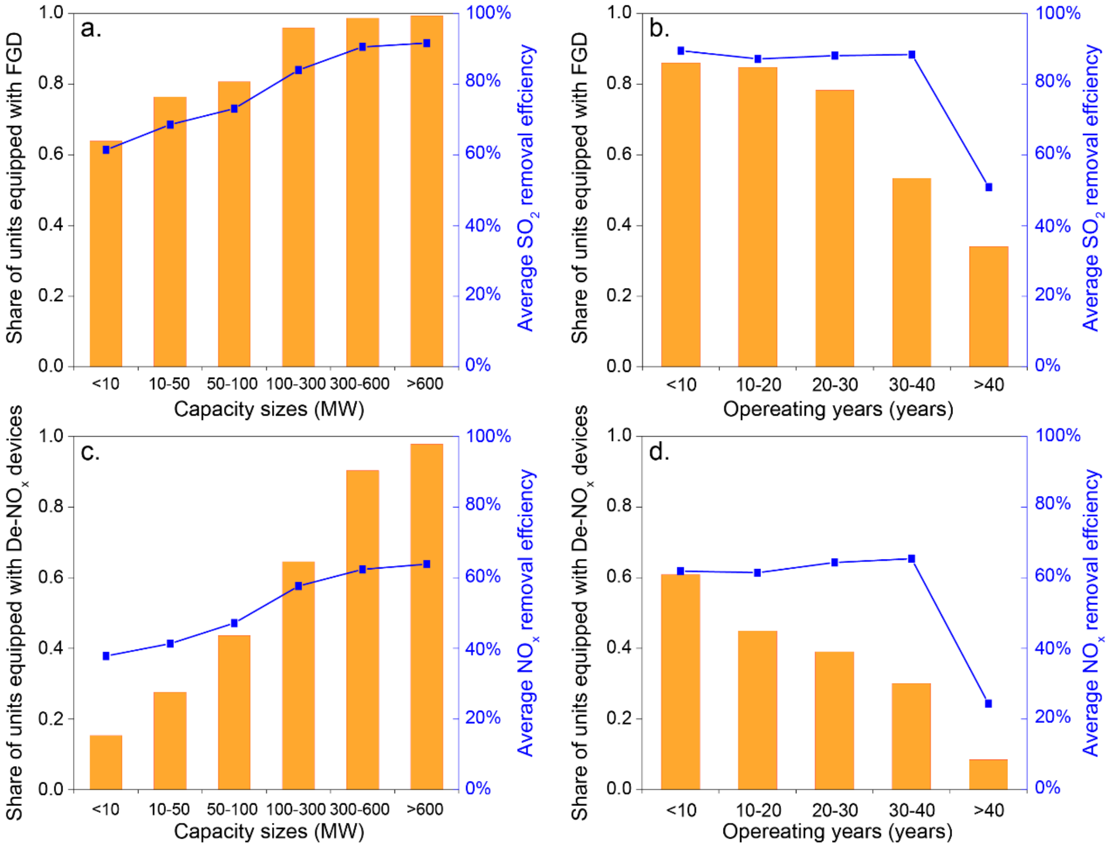

Figure S3. Share of operating units equipped with FGD and de-NO_x devices and their average coal-consumption-weighted removal efficiencies until 2015: (a) FGD by capacity sizes; (b) FGD by operating years; (c) de-NO_x devices by capacity sizes; (d) de-NO_x devices by operating years.

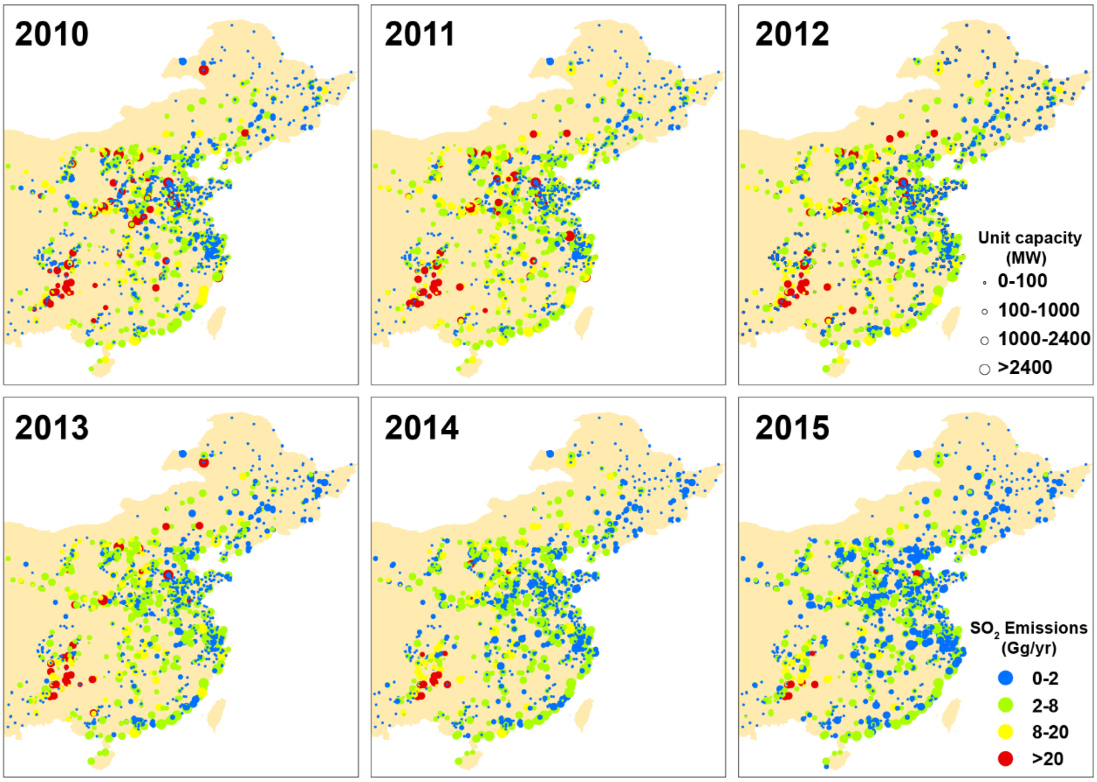

Figure S4. Evolution of SO_2 emissions from coal-fired power plants in China, 2010–2015. Units: Gg yr^{-1}.

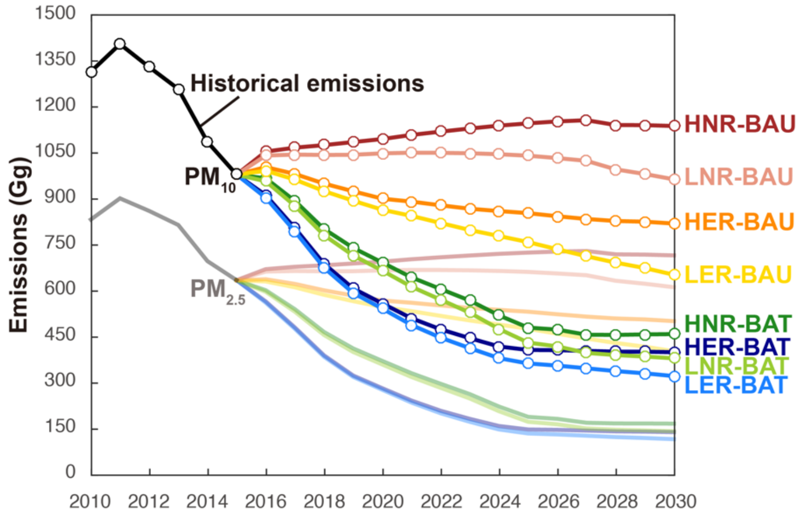

Figure S5. Emissions of PM_{10} of coal-fired power plants in China from 2010 to 2030 based on historical data and two sets of emission scenario groups (HNR-BAU, HNR-BAT, HER-BAU, and HER-BAT scenarios; LNR-BAU, LNR-BAT, LER-BAU, and LER-BAT scenarios). Note that the colored lines with transparency represent $PM_{2.5}$ emissions in each corresponding scenario for comparison.

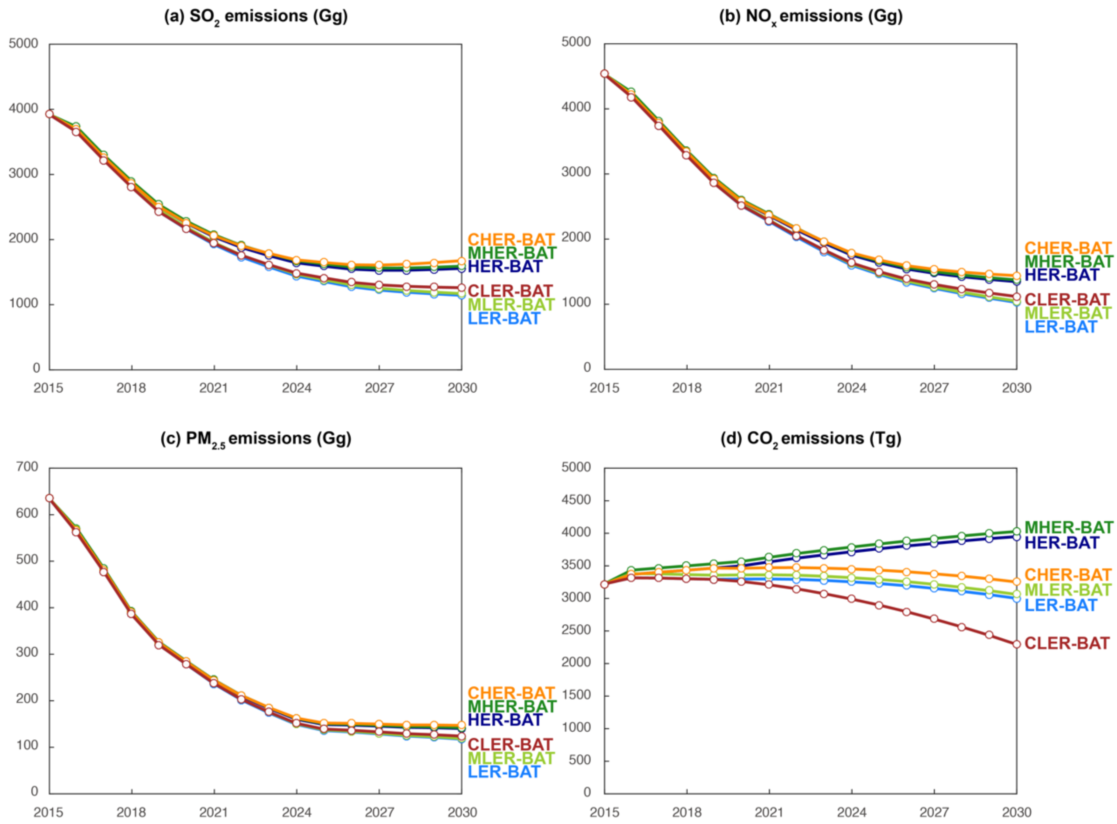

Figure S6. Emissions of air pollutants and CO_2 of coal-fired power plants in China from 2015 to 2030 based on two sets of sensitivity test scenarios (MHER-BAT, MLER-BAT scenarios; CHER-BAT, CLER-BAT scenarios) to compare with HER-BAT and LER-BAT scenarios: (a) SO_2; (b) NO_x; (c) $PM_{2.5}$; and (d) CO_2 emissions.

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