

SUPPLEMENT

Journal: Atmospheric Chemistry & Physics

Title: The effects of energy paths and emission controls and standards on future trends in China's emissions of primary air pollutants

Authors: Yu Zhao, Jie Zhang, Chris. P. Nielsen

Number of figures: 4 **Number of tables:** 3

Figure list

Figure S1. Provinces and regions of mainland China. Fine lines indicate the borders of provinces while thick lines indicate those of regions.

Figure S2. The penetrations of SO₂ and NO_x control devices for certain sectors in NPS-BAS and NPS-REF scenarios. (a) Coal-fired power plants (CPP); (b) Cement production (CEM); and (c) Other industrial coal-fired boilers (OIN-coal).

Figure S3. The penetrations of various dust collectors for selected sources in NPS-BAS and NPS-REF scenarios.

Figure S4. The annual NO₂ tropospheric vertical column in mainland China 2005-2010 from OMI satellite retrievals. The data for 2013 are the averages from January to October.

Table list

Table S1. The summary of emission standards for stationary sources included in this work.

Table S2. The removal efficiencies of air pollutant control devices (APCD) used in this work.

Table S3. The time schedule of implementation of emission standards for the transportation sector assumed in this work.

Figures

Figure S1.

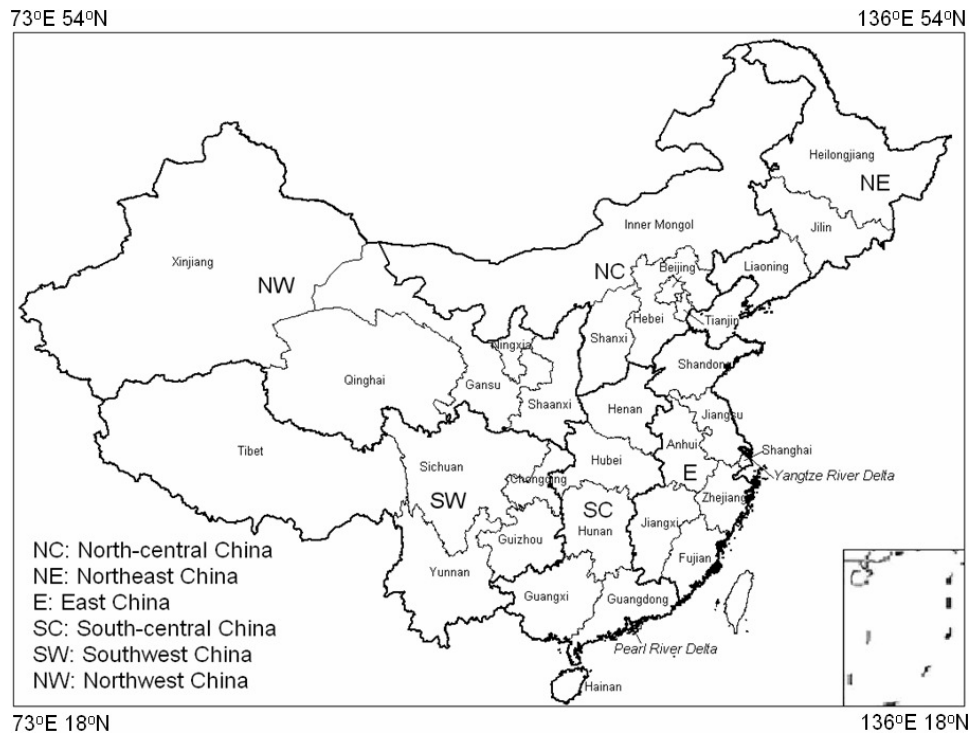
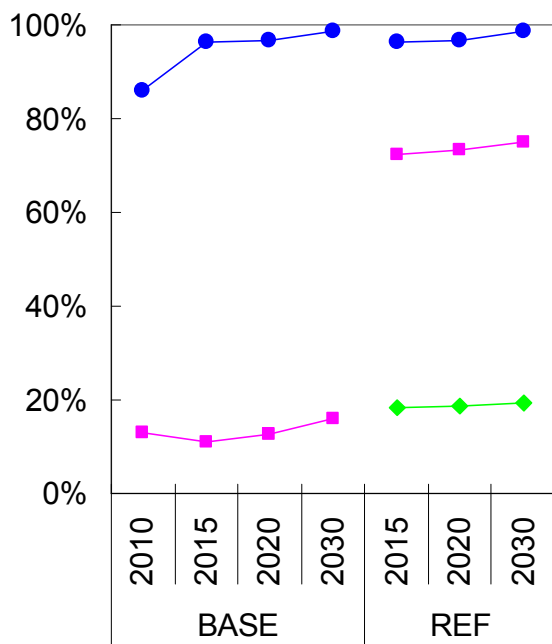
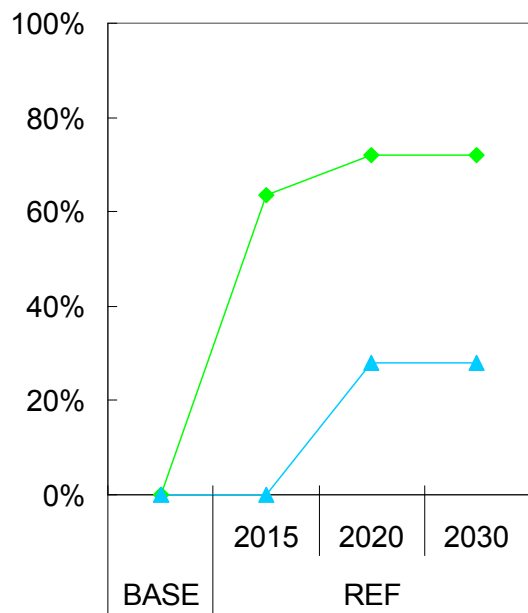


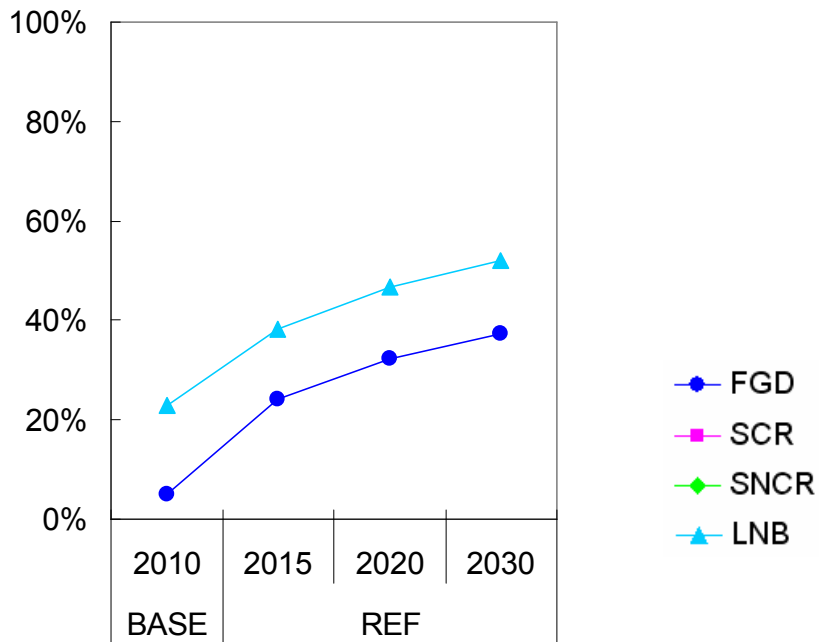
Figure S2.



(a) Coal-fired power plants

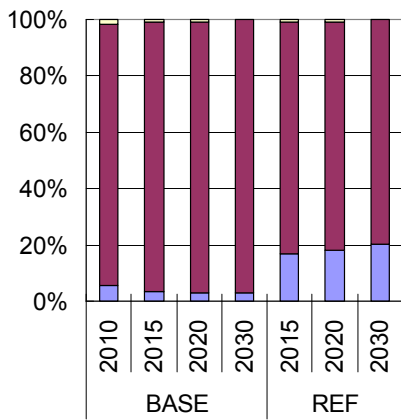


(b) Cement production (precalciner)

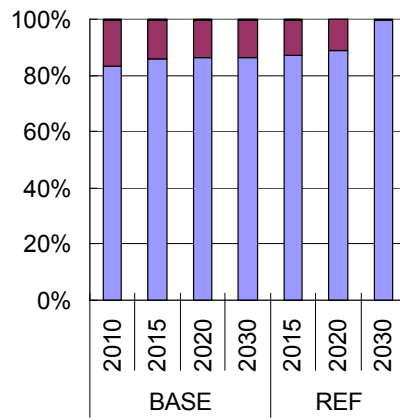


(c) Other industrial coal-fired boilers

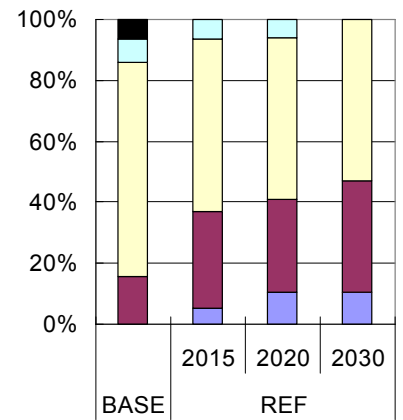
Figure S3.



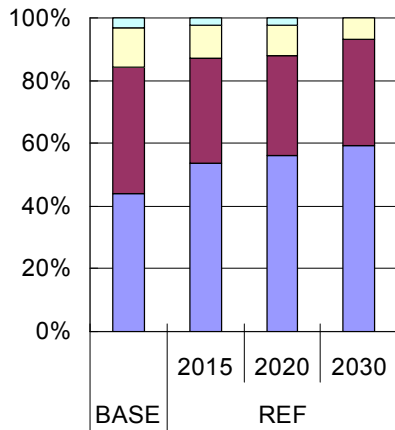
(a) Coal-fired power plants



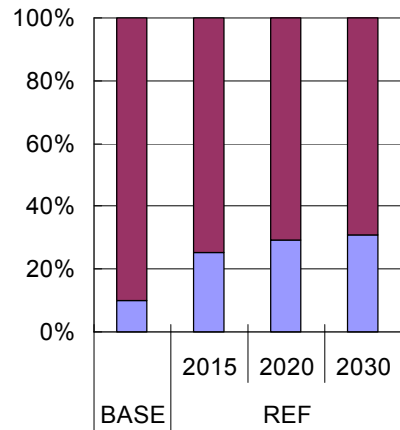
(b) Cement production (precalciner)



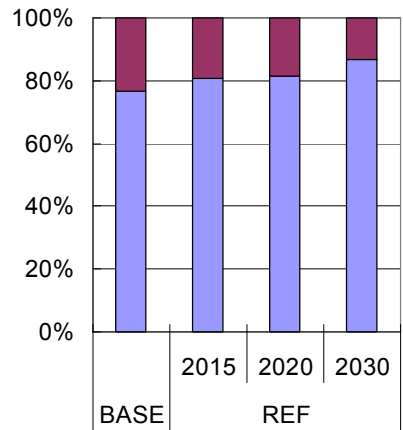
(c) Machinery coking plants



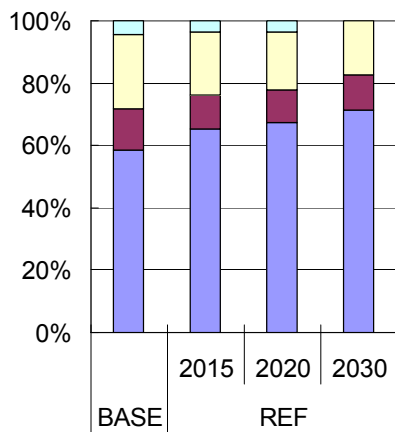
(d) Sintering



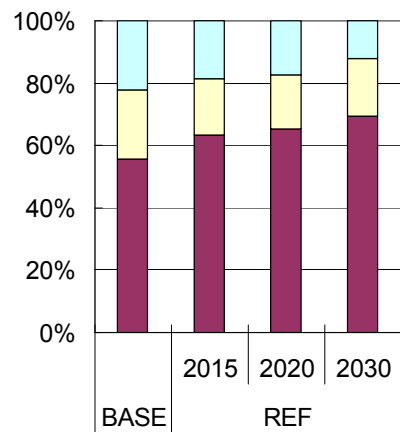
(e) Blast furnaces (iron production)



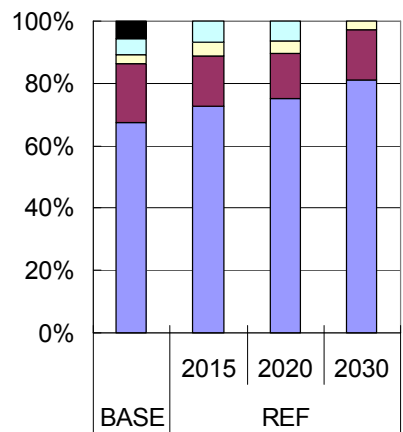
(f) Basic oxygen furnaces (steel making)



(g) Electric furnaces (steel making)

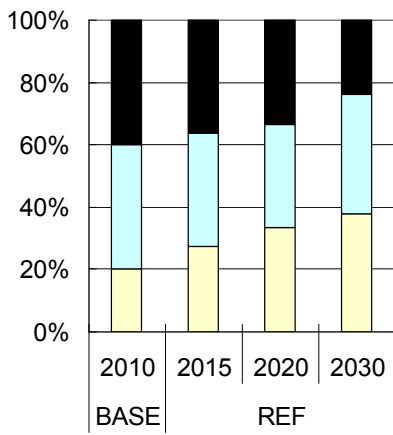


(h) Casting

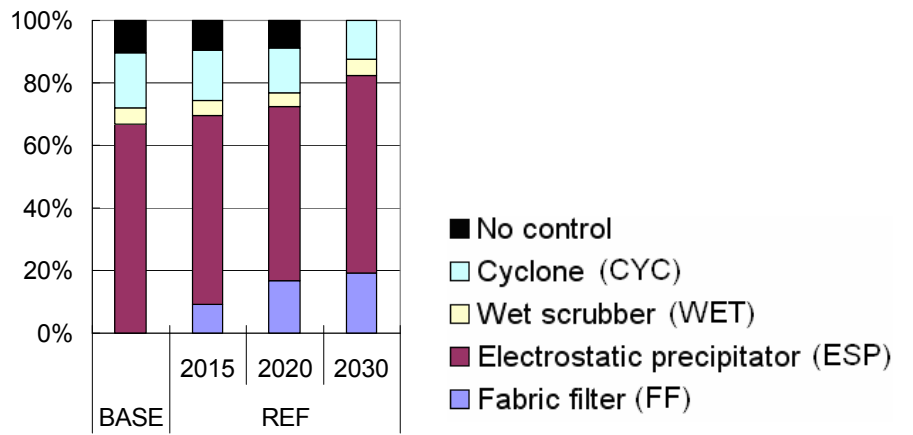


(i) Nonferrous metal (Cu, Zn and Pb)

Figure S3 (continued).

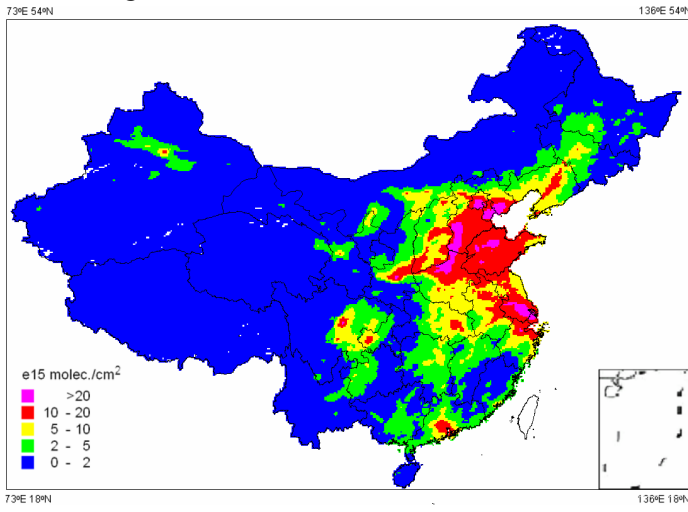


(j) Brick production

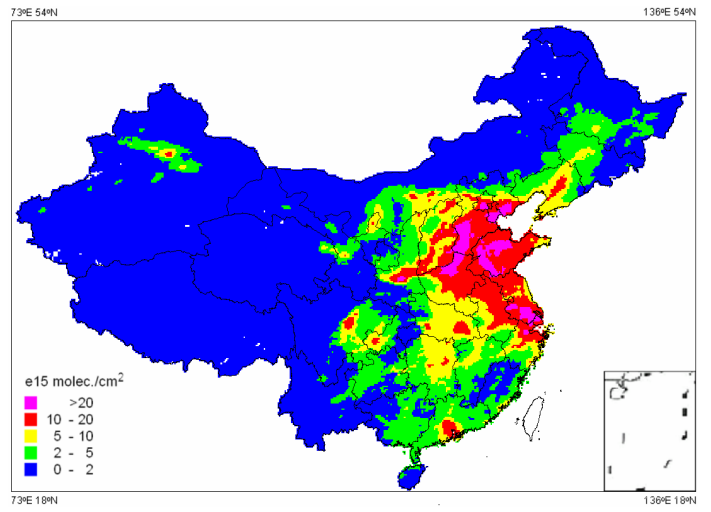


(k) Lime production

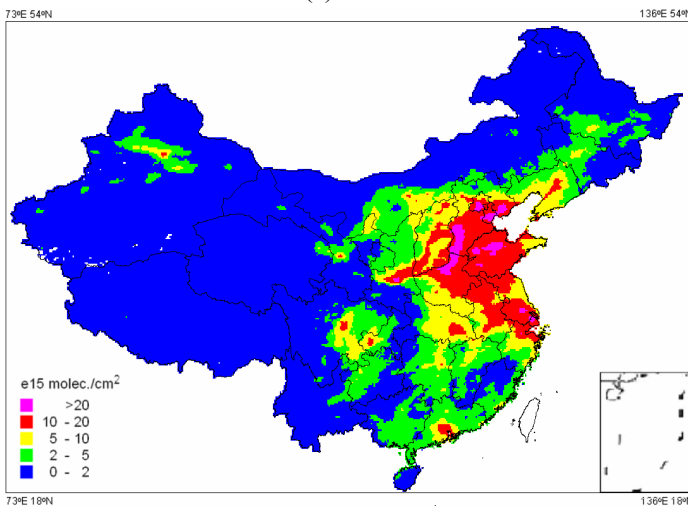
Figure S4



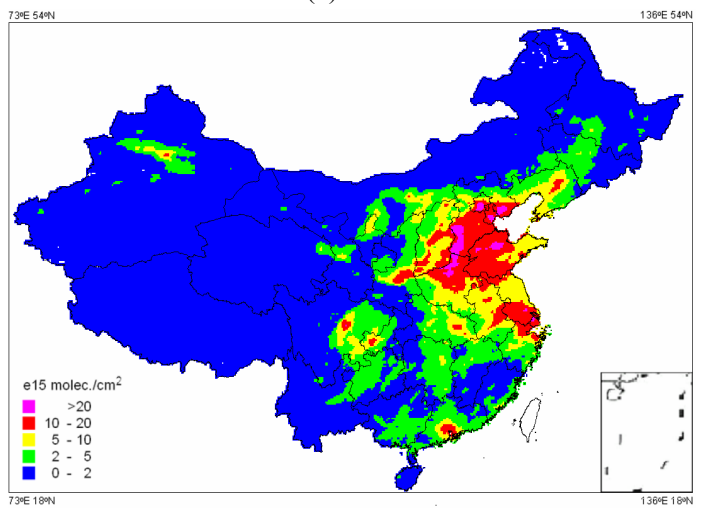
(a) 2010



(b) 2011



(c) 2012



(d) 2013 (averages of January-October)

Tables

Table S1. The summary of emission standards for stationary sources included in this work.

Sector	Standard	Issued time	Title
Power	GB 13223-2011	July, 2011	Emission standard of air pollutants for thermal power plants
Iron & steel production	GB 16171-2012	June, 2012	Emission standard of air pollutants for coking chemical industry
	GB 28662-2012	June, 2012	Emission standard of air pollutants for sintering and pelletizing of iron and steel industry
	GB 28663-2012	June, 2012	Emission standard of air pollutants for iron smelt industry
	GB 28664-2012	June, 2012	Emission standard of air pollutants for steel smelt industry
Non ferrous metal smelting	GB 25465-2010	Sep, 2010	Emission standard of pollutants for aluminum industry
	GB 25466-2010	Sep, 2010	Emission standard of pollutants for lead and zinc industry
	GB 25467-2010	Sep, 2010	Emission standard of pollutants for copper, nickel, cobalt industry
Brick production	N/A ^a	Nov, 2009 ^b	Emission standard of air pollutants for brick industry
Cement production	N/A ^a	-	Emission standard of air pollutants for cement industry

^a Proposed standard, not officially issued yet; ^b Proposed time.

Table S2. Average removal efficiencies of various air pollutant control devices (APCD) used in this work.

	SO ₂	NO _x	PM _{2.5}	PM _{2.5-10}	PM _{>10}	Data sources
Wet-FGD	80 ^a	-	53.74	81.21	92.63	Field survey (unpublished); filed tests and data integration (Zhao et al., 2010; 2011)
	70 ^b	-	53.74	81.21	92.63	MEP (2010); filed tests and data integration (Zhao et al., 2010; 2011)
	50 ^c	-	-	-	-	Field survey (unpublished); conservatively assumed
Other-FGD	30	-	-	-	-	Field tests (Zhao et al., 2010; 2011)
LNB	-	30	-	-	-	Field tests (Zhao et al., 2010; 2011)
SCR	-	60	-	-	-	Field survey (unpublished); personal communication with China Electricity Council director
SNCR	-	50	-	-	-	Field survey (unpublished); Zhao et al. (2013); conservatively assumed
FF	-	-	99.30	99.70	99.95	Field tests (Zhao et al., 2010; 2011)
ESP	-	-	92.31	96.97	99.46	Field tests and data integration (Zhao et al., 2010; 2011)
WET	20	-	67.40 ^d	85.74 ^d	96.51 ^d	Field tests (Zhao et al., 2010; 2011)
	20	-	56.96 ^e	84.01 ^e	96.49 ^e	Lei et al. (2011); Zhao et al. (2011)
CYC	-	-	13	75	90	Lei et al. (2011); Zhao et al. (2011)

^a For CPP in REF scenarios; ^b For CPP in BAS scenarios and other industrial sources (except for sintering); ^c For sintering process in REF scenarios; ^d For CPP; and ^e For sources other than CPP.

Table S3. The national time schedule of implementation of emission standards for transportation sector assumed in this work.

	Stage I	II	III	IV	V	VI
On-road vehicle ^a	2000	2005	2008	2013	2016	2026
On-road vehicle ^b	1999	2003	2005	2008	2013	2016
On-road vehicle ^c	2000	2005	2008	2011	2014	2021
RV ^a	2000	2005	2008	2013	2016	2026
RV ^{b, c}	2000	2005	2008	2011	2014	2021
Motorcycle	2003	2005	2010	-	-	-
Tractor	2006	2007	2014	-	-	-
Machine	2011	2014	2016	-	-	-
Train and inland ship	2011	2014	-	-	-	-

^a For BAS scenarios; ^b For REF scenarios in Beijing; ^c For REF scenarios in Tianjin, Shanghai, Jiangsu, Zhejiang and Guangdong.

REFERENCES

Lei, Y., Zhang, Q., He, K. B., and Streets, D. G.: Primary anthropogenic aerosol emission trends for China, 1990-2005, *Atmos. Chem. Phys.*, 11, 931-954, 2011.

Ministry of Environmental Protection in China (MEP): The handbook of emission factors of industrial sources for the first national survey on pollutant sources, 2010 (in Chinese).

Zhao, B., Wang, S. X., Liu, H., Xu, J. Y., Fu, K., Klimont, Z., Hao, J. M., He, K. B., Cofala, J., and Amann, M.: NO_x emissions in China: historical trends and future perspectives, *Atmos. Chem. Phys.*, 13, 9869-9897, 2013.

Zhao, Y., Nielsen, C. P., Lei, Y., McElroy, M. B., and Hao, J. M.: Quantifying the uncertainties of a bottom-up emission inventory of anthropogenic atmospheric pollutants in China, *Atmos. Chem. Phys.*, 11, 2295-2308, 2011.

Zhao, Y., Wang, S. X., Nielsen, C. P., Li, X. H., and Hao, J. M.: Establishment of a database of emission factors for atmospheric pollutants from Chinese coal-fired power plants, *Atmos. Environ.*, 44, 1515-1523, 2010.