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Supplementary Information for

Energy and air pollution benefits of household fuel policies in northern China

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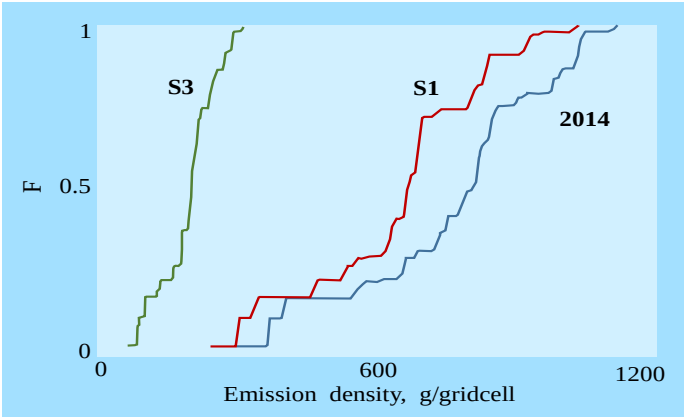

Fig. S1 Cumulative frequency distributions of emission densities (g/gridcell) of primary $PM_{2.5}$ from residential sector in the study region for 2014 baseline and two scenarios of S1 and S3 in 2021.

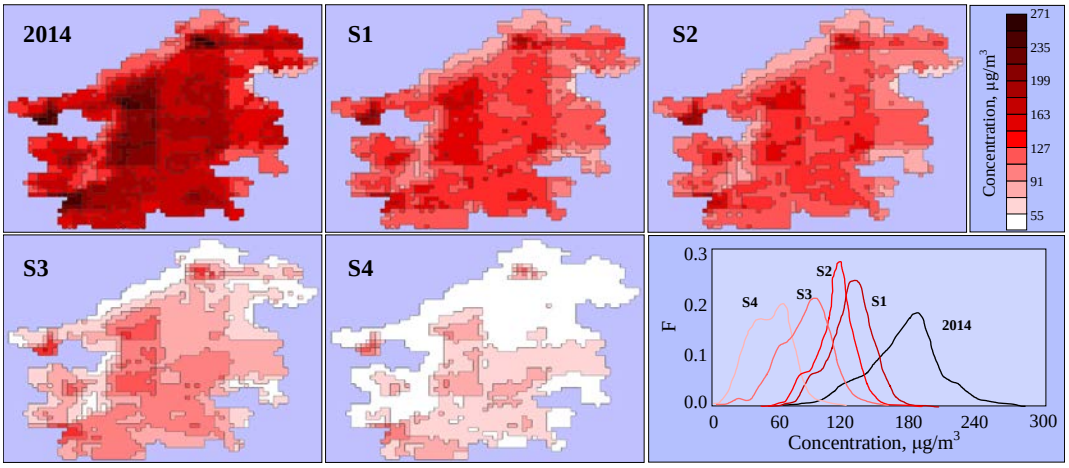

Fig. S2 Spatial distribution of exposure levels as population weighted $PM_{2.5}$ concentrations contributed from all emission sources at the four scenarios and 2014 baseline. The spatial resolution is 0.125° by 0.125°. Frequency distributions based on average gridcell exposures are also shown.

Table. S1 Estimated $PM_{2.5}$ concentrations (μg/m^3) and time-activity patterns in the kitchen, living/bed rooms, and outdoors in the study region. The percentages in each group might not sum to 100% due to the rounding operation.

	Outdoor and indoor $PM_{2.5}$ concentration						*Time-activity patterns in the study region*							
	Location	2014	S1	S2	S3	S4	M<5	M5-14	M15-65	M>65	F<5	F5-14	F15-65	F>65
Non-heating	Outdoor	107	73	71	66	61	10%	7%	19%	20%	9%	7%	18%	16%
	Kitchen	130	122	120	115	112	5%	2%	3%	4%	4%	5%	11%	22%
	Living/Bed Room	92	91	91	89	89	86%	91%	78%	77%	87%	89%	71%	62%
Heating	Outdoor	107	73	71	66	61	10%	5%	13%	13%	10%	5%	10%	10%
	Kitchen	301	293	283	166	112	24%	3%	6%	7%	24%	4%	10%	24%
	Living/Bed Room	214	209	202	125	89	67%	91%	81%	80%	66%	90%	79%	65%

Table. S2 The estimated annual per-household electricity and PNG consumption for heating in the study region.

PNG/m^3	*Electricity/kWh*
900[i]	4515[ii]
960[iii]	5400[iii]
1050[ii]	6000[iv]
1200[v]	6300[vi]
1200[i]	6480[iii]
1300[vii]	9565[viii]
1618[iv]	9840[ix]
	10000[i]
	12000[i]

[i] https://www.tuliu.com/read-61748.html. Accessed on 29th, August, 2018.
[ii] http://k.sina.com.cn/article_6432403492_17f66b024001004q4d.html?cre=tianyi&mod=pcpager_fintouti. Accessed on 29th, August, 2018.
[iii] https://www.letscorp.net/archives/126703. Accessed on 29th, August, 2018.
[iv] http://www.dl78.com/news/195-cn.html. Accessed on 29th, August, 2018.
[v] http://guba.eastmoney.com/news,gssz,727778455.html. Accessed on 29th, August, 2018.
[vi] http://www.sc.sgcc.com.cn:8080/html/main/col9/2017-11/28/20171128142349924865361_1.html. Accessed on 29th, August, 2018.
[vii] http://society.people.com.cn/n1/2017/1219/c1008-29714583.html. Accessed on 29th, August, 2018.
[viii] http://www.bjstats.gov.cn/zxfb/201712/t20171204_388348.html. Accessed on 29th, August, 2018.
[ix] http://www.dinuanwang.com/baike/dongtai/861.html. Accessed on 29th, August, 2018.

Table. S3 Total residential energy consumption in the study region with targeted

substitution (S3)

Year	*Coal Tg/y*	*Honeycomb Tg/y*	*Charcoal Tg/y*	*Fuelwood Tg/y*	*Brushwood Tg/y*	*Straw Tg/y*	*Corncob Tg/y*	*LPG Tg/y*	*Biogas Tg/y*	*Electricity 10^9kWh/y*	*PNG $10^9 m^3/y$*
1992	16.2	8.0	0.1	34.1	19.1	27.9	14.6	0.2	0.0	0.3	0.0
1993	16.2	8.3	0.1	32.7	18.5	26.9	14.1	0.2	0.0	0.4	0.0
1994	16.2	8.6	0.1	31.3	17.9	25.9	13.7	0.2	0.0	0.4	0.0
1995	16.2	8.9	0.1	29.9	17.3	24.9	13.3	0.2	0.0	0.5	0.0
1996	16.2	9.2	0.1	28.5	16.8	23.9	12.9	0.3	0.0	0.5	0.0
1997	16.3	9.4	0.1	27.1	16.2	23.0	12.5	0.3	0.0	0.5	0.0
1998	16.3	9.7	0.1	25.6	15.6	22.0	12.1	0.3	0.0	0.6	0.0
1999	16.3	10.0	0.1	24.2	15.0	21.0	11.7	0.3	0.0	0.6	0.0
2000	16.3	10.3	0.0	22.8	14.4	20.0	11.3	0.4	0.0	0.6	0.0
2001	16.3	10.6	0.0	21.4	13.8	19.0	10.9	0.4	0.0	0.7	0.0
2002	16.3	10.8	0.0	20.0	13.2	18.0	10.5	0.4	0.0	0.7	0.0
2003	16.1	10.3	0.0	18.4	12.3	16.9	9.9	0.4	0.0	1.0	0.0
2004	16.0	9.8	0.0	16.7	11.4	15.7	9.3	0.5	0.0	1.2	0.0
2005	15.8	9.4	0.0	15.1	10.5	14.6	8.7	0.5	0.0	1.5	0.0
2006	15.6	8.9	0.0	13.5	9.6	13.5	8.2	0.5	0.1	1.8	0.0
2007	15.5	8.4	0.0	11.9	8.7	12.3	7.6	0.6	0.1	2.0	0.0
2008	14.9	7.7	0.0	11.0	8.1	11.4	7.2	0.6	0.1	2.4	0.0
2009	14.4	7.0	0.0	10.1	7.5	10.4	6.8	0.6	0.1	2.8	0.0
2010	13.8	6.4	0.0	9.2	6.9	9.5	6.3	0.6	0.1	3.3	0.0
2011	13.3	5.7	0.0	8.3	6.3	8.5	5.9	0.6	0.1	3.7	0.0
2012	12.7	5.0	0.0	7.4	5.7	7.6	5.5	0.6	0.1	4.1	0.0
2013	11.8	4.3	0.0	6.4	5.1	6.6	4.9	0.7	0.1	4.5	0.0
2014	11.1	3.7	0.0	5.5	4.6	5.8	4.4	0.7	0.1	5.0	0.0
2015	10.4	3.3	0.0	4.8	4.2	5.1	4.0	0.7	0.1	5.6	0.0
2016	9.9	2.9	0.0	4.3	3.8	4.6	3.7	0.7	0.1	6.3	0.0
2017	9.3	2.6	0.0	3.8	3.5	4.1	3.4	0.8	0.1	7.2	1.3
2018	7.6	2.2	0.0	3.2	3.0	3.5	2.9	0.9	0.1	18.0	2.1
2019	5.9	1.8	0.0	2.7	2.4	2.9	2.4	1.1	0.2	28.8	2.9
2020	4.2	1.3	0.0	2.1	1.9	2.3	1.9	1.3	0.2	39.7	3.7
2021	2.5	0.9	0.0	1.5	1.4	1.7	1.3	1.5	0.2	50.5	4.5

Table. S4 Emission factors for residential fuels combustion in 2014 (g/kg)

	Coal	*Honeycomb*	*Charcoal*	*Fuelwood*	*Brushwood*	*Straw*	*Corncob*	*LPG*	*Biogas*
CO_2	1871.7	1871.5	359.0	0.0	0.0	0.0	0.0	2968.6	59.6
$PM_{2.5}$	9.7	7.0	5.0	2.6	7.7	6.7	6.9	0.5	0.1

SO_2	14.5	12.0	0.7	0.1	0.3	0.3	0.4	0.2	0.7
NO_x	1.9	1.6	1.1	1.4	1.0	2.0	2.0	2.1	0.2
OC	5.8	4.5	2.8	1.3	3.9	2.6	2.7	0.1	0.0
CO	103.6	48.5	69.6	105.0	85.2	93.5	94.2	9.7	2.0
BC	4.8	0.2	1.6	0.7	2.8	0.8	0.7	0.1	0.0
PM_{10}	12.5	7.2	5.3	2.6	10.2	6.9	7.1	0.5	0.1
NH_3	0.9	0.9	1.3	0.9	4.6	0.5	2.5	0.2	0.3

Table. S5 Indoor mean $PM_{2.5}$ concentration for fuels (μg/m^3)

		coal	*crop residues*	*wood*	*clean*
Non-heating	Kitchen	133	213	239	112
	Living/Bed Room	99	99	104	89
Heating	Kitchen	283	434	547	112
	Living/Bed Room	211	267	359	89