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Supplement of

Advantages of a city-scale emission inventory for urban air quality research and policy: the case of Nanjing, a typical industrial city in the Yangtze River Delta, China

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Tables

Table S1. Summary of activity levels by sector for Nanjing emission inventory 2010-2012. Unless noted, the data are obtained from the databases of Environmental Statistics and Pollution Source Census, or Nanjing Statistical Yearbook.

Sector	Parameter	2010	2011	2012
Power plant	Electricity generation/10^7kWh	3262	4832	5147
	Coal consumption/Million metric tons (Mt)	18.2	23.0	22.8
Iron & steel plant	Coke production/Kilo metric tons (kt)	3931	4022	4446
	Iron production/kt	10345	11330	12143
	Steel production/kt	10541	11518	12257
	Coal consumption/kt	7748	7856	8074
Cement	Clinker production/kt	9428	8085	9268
	Cement production/kt	9802	9512	10298
	Coal consumption/kt	1264	1200	1536
Refineries and chemical plant	Gasoline production/kt	2437	2417	2682
	Diesel production/kt	6937	6409	5828
	Kerosene production/kt	1656	2013	2316
	Liquefied petroleum gas production/kt	1013	1096	1077
Other industry plant	Waste incineration/metric tons (t)	20012	19622	19748 [a]
	Municipal solid waste landfill/t	1771700	1963500	1976091 [a]
	Coal consumption/kt	2875	581	1047
Residential & commercial	Coal consumption/kt	298	298	298
Gas station	Gasoline sales/kt	854	953 [b]	1092 [b]
Fugitive dust	Construction site area/10^4 m^2 [c]	4760	5663	6050

Table S1. Continued.

Sector	Parameter	2010	2011	2012
Solvent use	Coating-architecture/t [d]	21115	23962	24224
	Coating-vehicle production/t [e]	7259	6833	7300
	Coating-vehicle repair/t [f]	3604	7338	8547
	Adhesive-architecture/t [d]	53019	60167	60825
	Adhesive-wood processing/t [g]	46584	49017	62445
Transportation	Gasoline vehicle population	738485	875460	1066010
	Diesel vehicle population	79734	89201	98309
	Motorcycle population	355208	344758	335830
	Railway freight tonnage originated/kt	15936	18205	18058
	Air transportation-total cargo/kt	234	247	248

[a] Scaled based on resident population of the city.

[b] Scaled based on vehicle population of the city.

[c] Internal data from local Environmental Protection Agency

[d] Calculated based on the building area of the city.

[e] Calculated based on the annual production of vehicles in the city.

[f] Calculated based on vehicle population of the city.

[g] Downscaled from national level based on gross domestic production (GDP).

Table S2. Technology distribution by vehicle type (share of each technology level out of each vehicle type) in Nanjing, for the year 2012.

Vehicle type		Pre-China I	China I	China II	China III	China IV
Passenger vehicle	Mini bus	13.39%	54.44%	6.65%	14.63%	10.89%
	Light-duty	1.61%	8.91%	17.97%	37.43%	34.08%
	Medium-duty	28.11%	18.94%	32.40%	16.90%	3.65%
	Heavy-duty	6.37%	14.45%	26.27%	42.98%	9.94%
Truck	Mini truck	2.86%	0.00%	57.14%	40.00%	0.00%
	Light-duty	2.33%	22.01%	11.64%	46.24%	17.79%
	Medium-duty	15.84%	33.66%	16.87%	28.26%	5.37%
	Heavy-duty	2.57%	12.15%	14.48%	56.39%	14.41%
Motorcycle		14.62%	18.43%	44.69%	22.26%	0.00%
Taxi		0.06%	0.00%	1.00%	44.49%	54.45%
Bus	Medium-duty	0.00%	1.67%	23.96%	59.61%	14.76%
	Heavy-duty	0.70%	4.36%	35.68%	57.15%	2.11%
Sum		5.16%	12.46%	23.68%	34.10%	24.60%

Table S3. Annual average vehicle kilometers traveled (VKT), average age and average accumulated mileage of the fleet in Nanjing, for the year 2012.

	Annual average VKT (km)	Average age (year)	Average accumulated mileage (km)
Minibus	25574	3.86	98716
Light-duty passenger vehicle	25574	3.86	98716
Medium-duty passenger vehicle	66400	6.73	446872
Heavy-duty passenger vehicle	66400	6.73	446872
Mini truck	44000	4.4	193600
Light-duty truck	44000	4.4	193600
Medium-duty truck	63300	7.23	457659
Heavy-duty truck	105600	3.93	415008
Motorcycle	7303	6.42	46885
Taxi	138000	2.18	300840
Bus	43940	4.51	198169

Table S4. The unabated emission factors (EF) for power plant and typical industrial sources. The numbers for BC and OC are the mass fractions of corresponding carbonaceous aerosol species to $PM_{2.5}$ (dimensionless). The units for other species are kg/t-coal for coal-fired power plant and cement clinker production, and kg/t-product for other sources unless specifically noted.

Sector	Process/source	SO_2	NO_X	$PM_{2.5}$	$PM_{2.5-10}$	$PM_{>10}$	BC	OC	VOCs	CO	CO_2
Coal-fired power plant	Pulverized combustion	19S/18S[a]	4.8/5.4/4.2/6.2/9.2[b]	0.4A[c]	1.1A[c]	5.4A[c]	0.01[c]	0[c]	0.15[d]	0.7/2[e]	2058/1358/2320[f]
	Grate stoker	17S[a]		0.10A[c]	0.17A[c]	1.24A[c]	0.20[c]	0.04[c]		2.6[e]	
	Circulating fluidized bed	12S[a]		0.45A[c]	1.09A[c]	3.26A[c]	0.01[c]	0[c]		2.1[e]	
Cement production	Clinker production	5.1S[g]	13[g]	21[h]	28[h]	69[h]	0.01[h]	0.02[h]	1.4[d]	12[e]	1731[f]
	Process			10[h]	24[h]	106[h]	0.01[h]	0.02[h]			
Iron & steel production	Machinery coking	1.35[i]	1.70[j]	1.3[h]	0.8[h]	2.9[h]	0.40[h]	0.35[h]	2.40[k]	0.10[l]	2067[f]
	Sintering	2.82[g]	0.64[g]	3.29[h]	3.76[h]	39.95[h]	0.01[h]	0.05[h]	0.25[g]	11[e]	
	Pig iron	0.11/0.10[m]	0.17[g]	7.32[h]	5.86[h]	35.6[h]	0.19[h]	0.04[h]		4.20[l]	
	Steel			17.6/5.4[h]	5.2/1.6[h]	17.2/5.2[h]		0.2/0.02[h]	0.06[g]	22[l]/9[e]	
Non-ferrous metal smelting	Aluminum	6[m]		17.1[h]	8.6[h]	19.4[h]					
	Lead	80[h]		205[h]	25[h]	20[h]					
	Copper	212[h]		211[h]	25.8[h]	20.6[h]					520[f]
	Zinc	80[h]		161[h]	19.6[h]	15.7[h]					1720[f]
Other production	Brick	0.53[m]	0.13[m]	0.27[h]	0.44[h]	2.99[h]	0.40[h]	0.35[h]	0.20[k]	150[e]	1731[f]
	Lime	1.0[h]	1.6[h]	1.8[h]	9[h]	79.2[h]	0.02[h]	0.04[h]		115[e]	750/1731[f]
	Glass			9.65[h]	0.42[h]	0.53[h]			4.4[k]		200[f]
	Sulfuric acid	3.4[h]									

Table S4. Continued

Sector	Process/source	SO_2	NO_X	$PM_{2.5}$	$PM_{2.5-10}$	$PM_{>10}$	BC	OC	VOCs	CO	CO_2
Other production	Nitric acid		7.1[h]								
	Ammonia	3.0[h]	0.9[h]						4.7[k]	142[e]	4582/3273/2104[f]
	Refinery	0.9[h]	0.3[h]	0.10[h]	0.02[h]				-	10[e]	

[a] Zhao et al. (2010). S represents the sulfur content, in percent, of the coal as fired. Numbers for pulverized combustion indicate EFs for anthracite and bituminous combustion, respectively.

[b] Zhao et al. (2010). Numbers indicate EFs for tangentially-fired low NO_X burner burning bituminous (≥300MW), swirl low NO_X burner burning bituminous (≥ 300MW), low NO_X burner burning bituminous (<300MW), burner without low NO_X combustion burning bituminous (<300MW), and burner without low NO_X combustion burning anthracite (<300MW), respectively. .

[c] Zhao et al. (2010). A represents the ash content, in percent, of the coal as fired.

[d] Bo et al. (2008).

[e] Zhao et al. (2012a). Numbers for pulverized combustion indicate EFs for units (≥200MW)/units (<200MW), respectively. The unit for brick and lime production is kg/t-coal.

[f] Zhao et al. (2012b). Numbers for coal-fired power plant indicate EFs for bituminous/lignite/anthracite combustion, respectively. Numbers for ammonia production indicate EFs for processes using coal/oil/gas as energy, respectively. Numbers for lime production indicate EFs for calcinations of carbonates (kg/t-lime) and combustion processes (kg/t-coal), respectively. The unit for brick production is kg/t-coal.

[g] Lei (2008).

[h] Zhao et al. (2013). The unit for cement is kg/t-production. Numbers for steel production indicate EFs for basic oxygen furnace/electric arc furnace, respectively.

[i] He (2006)

[j] Huo et al. (2012)

[k] Wei (2009)

[l] From onsite investigations in Nanjing.

[m] MEP (2010). Numbers for SO_2 from pig iron production indicate EFs for blast furnaces with gas volume over 2000 m^3/350-2000 m^3, respectively.

Table S5. The emissions (estimated by this work) and ambient concentrations (Yu et al., 2014) of SO_2, NO_X/NO_2, $PM_{2.5}$, PM_{10} and CO for August 16-24, 2012 and August 16-24, 2013 (the period of Youth Asian Games, 2013) in Nanjing.

		SO_2	NO_X/NO_2	$PM_{2.5}$	PM_{10}	CO
Emissions (metric tons)	Aug 16-24, 2012	3387	5073	1814	2365	21087
	Aug 16-24, 2013	2608	3501	1433	2034	14128
	Reduction rate	23%	31%	21%	14%	33%
Concentrations (ug/m^3)	Aug 16-24, 2012	27	41	43	89	896
	Aug 16-24, 2013	21	30	38	73	699
	Reduction rate	22%	27%	18%	12%	22%

Figures

Figure S1.

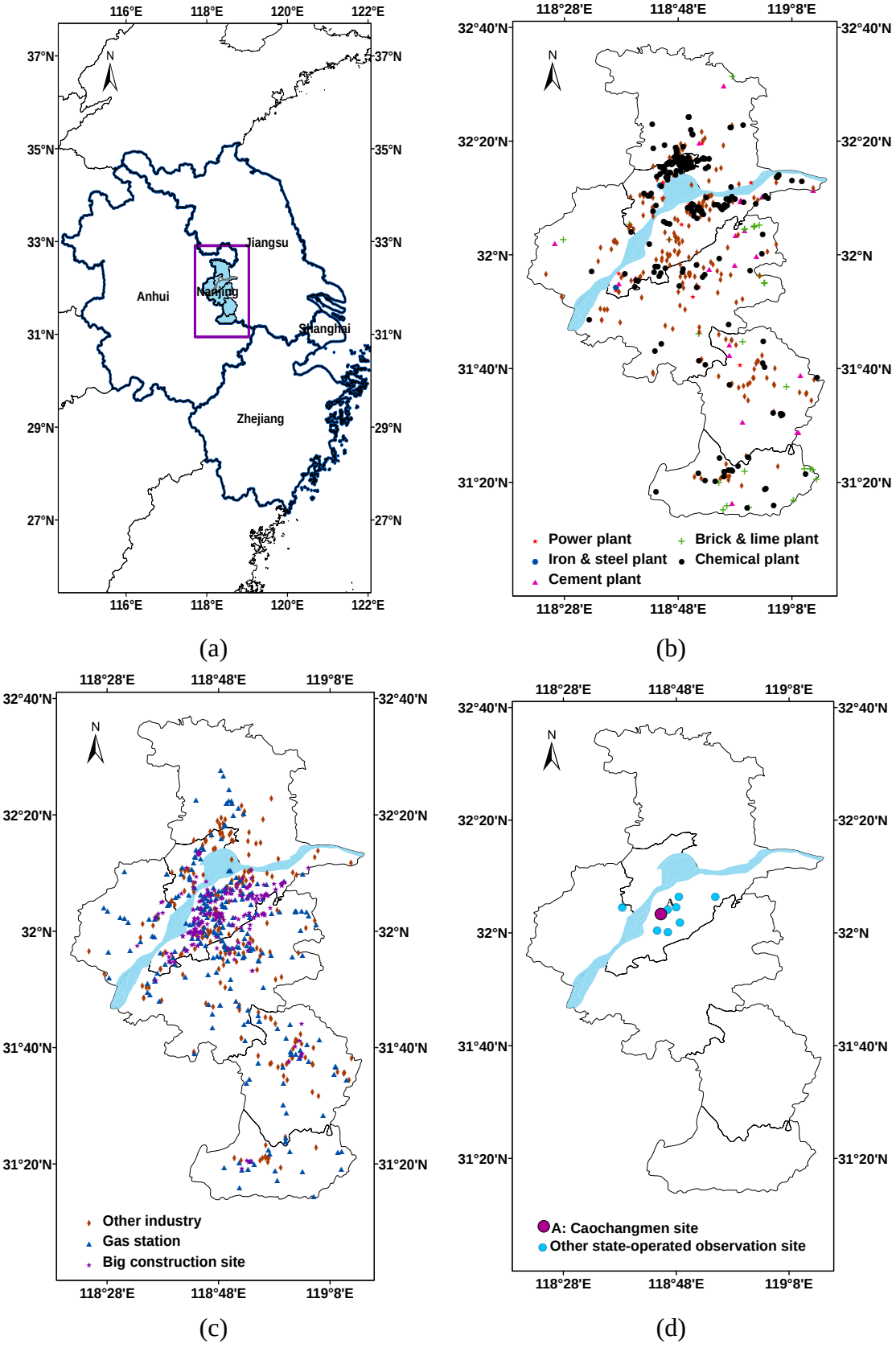


Figure S2.

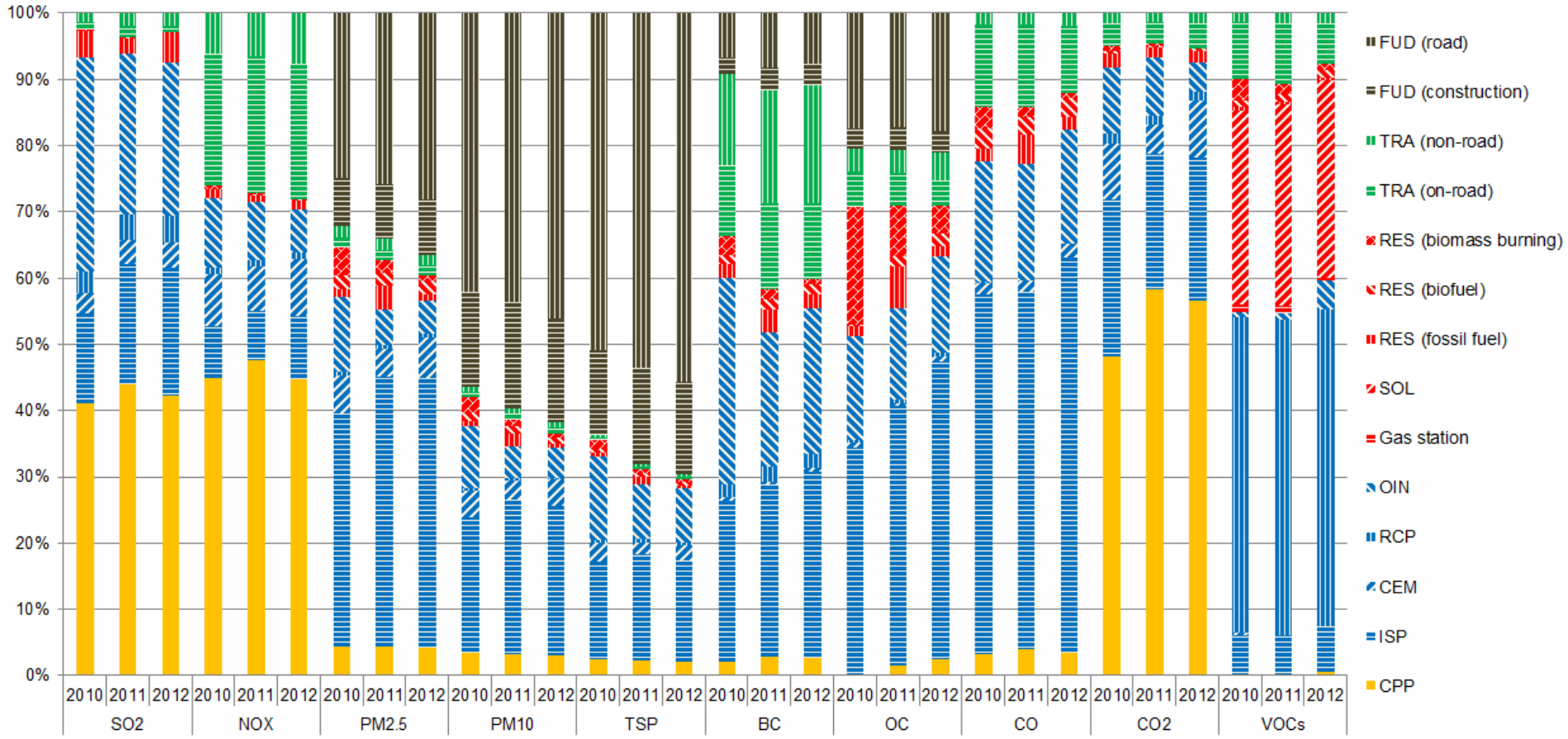

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2010 2011 2012
SO2
NOX
PM2.5
PM10
TSP
BC
OC
CO
CO2
VOCs
FUD (road)
FUD (construction)
TRA (non-road)
TRA (on-road)
RES (biomass burning)
RES (biofuel)
RES (fossil fuel)
SOL
Gas station
OIN
RCP
CEM
ISP
CPP

Figure S3.

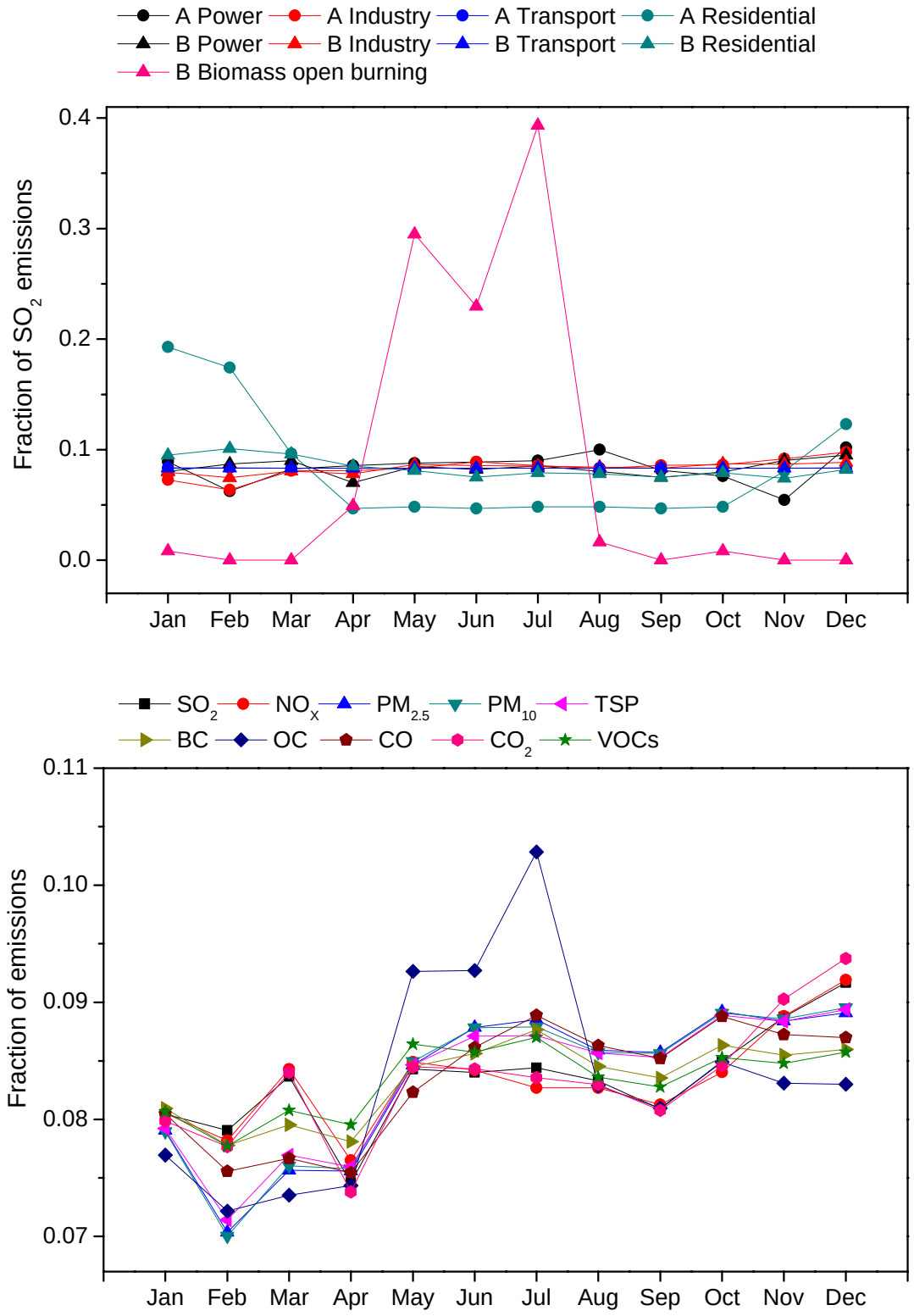

A Power
A Industry
A Transport
A Residential
B Power
B Industry
B Transport
B Residential
B Biomass open burning
Fraction of SO2 emissions
0.4
0.3
0.2
0.1
0.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
SO2
NOX
PM2.5
PM10
TSP
BC
OC
CO
CO2
VOCs
Fraction of emissions
0.11
0.10
0.09
0.08
0.07

Figure S4.

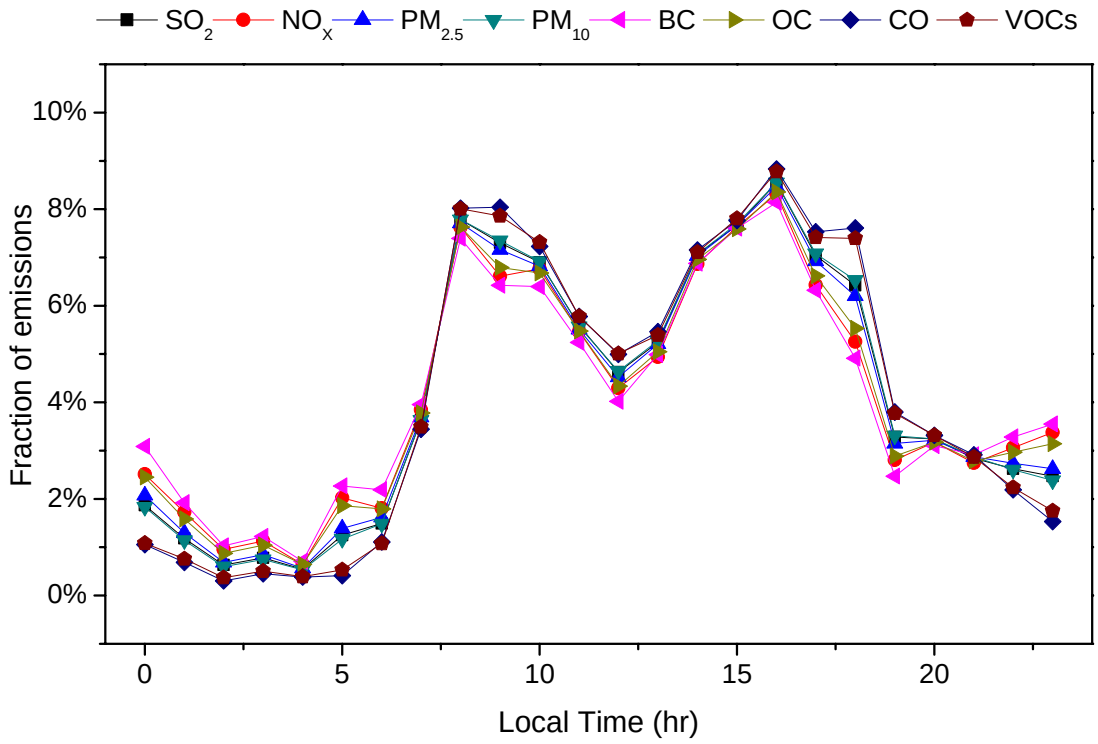

SO2
NOX
PM2.5
PM10
BC
OC
CO
VOCs
Fraction of emissions
10%
8%
6%
4%
2%
0%
0
5
10
15
20
Local Time (hr)

Figure S5.

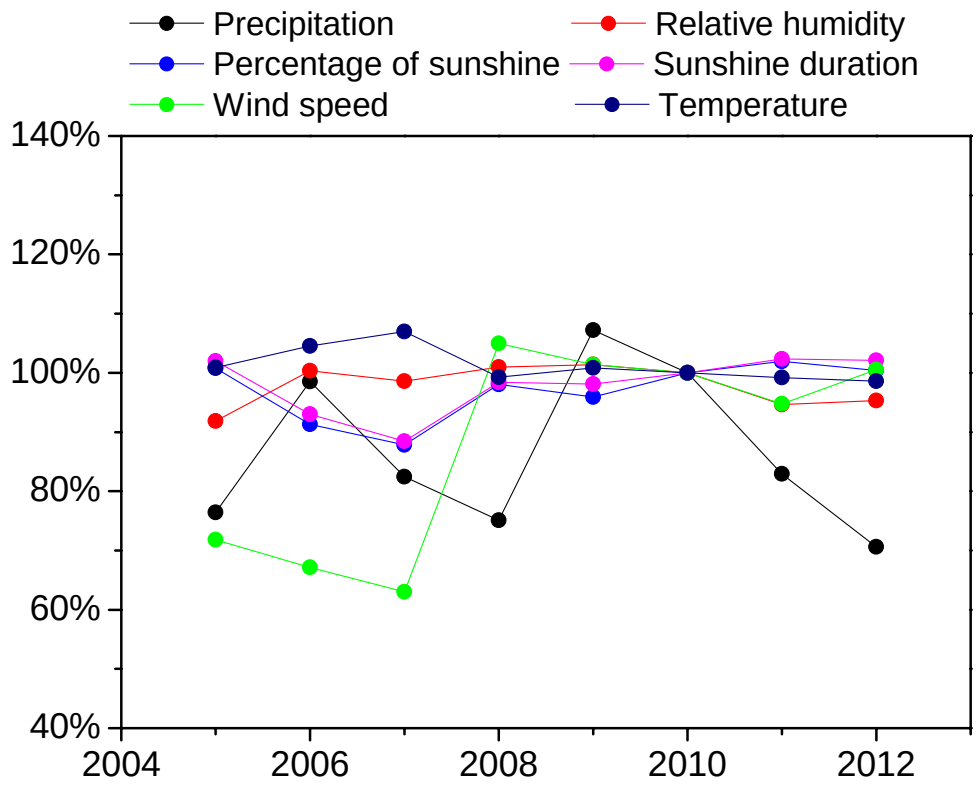

Precipitation
Relative humidity
Percentage of sunshine
Sunshine duration
Wind speed
Temperature
140%
120%
100%
80%
60%
40%
2004
2006
2008
2010
2012

Figure S6.

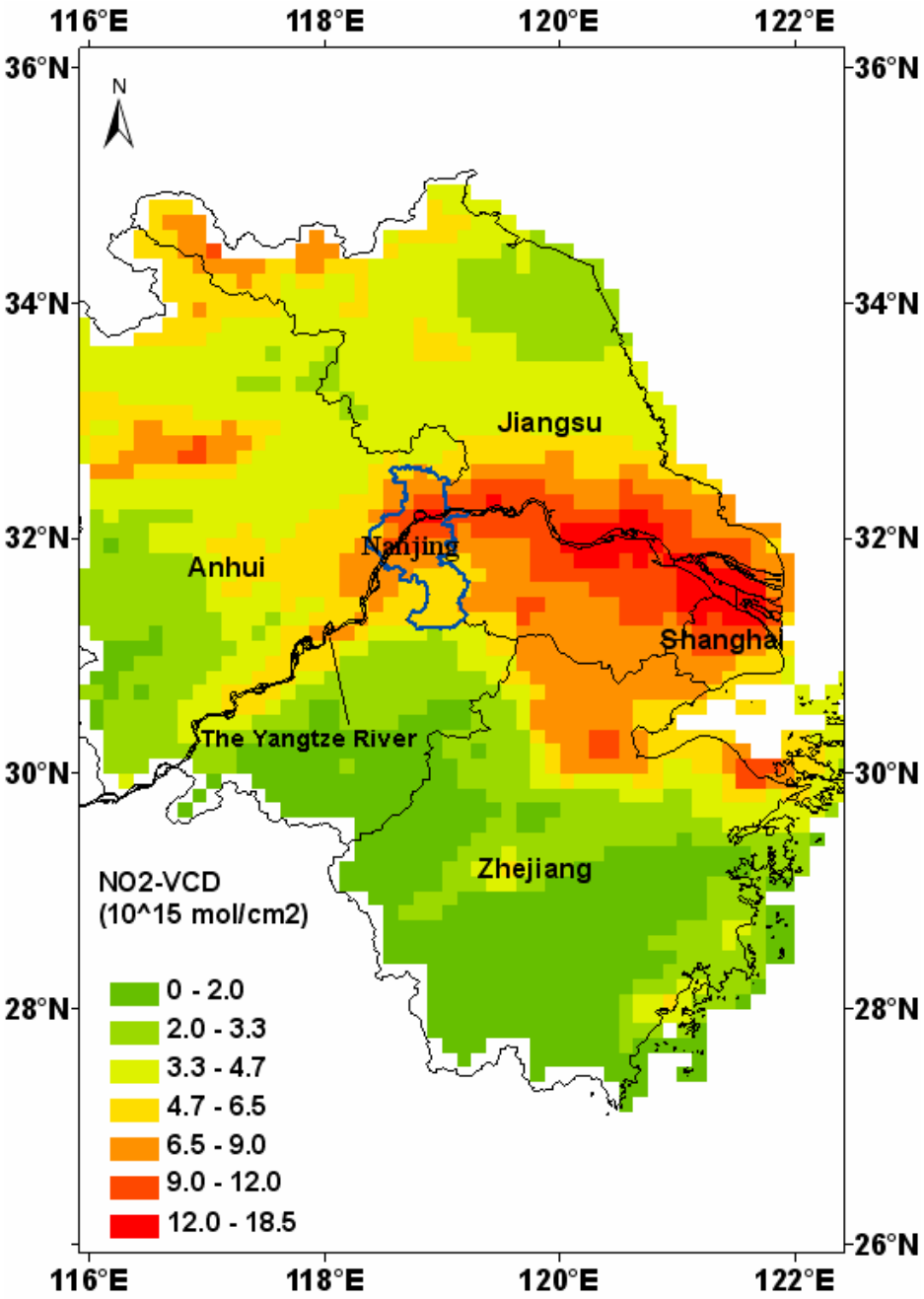

116°E
118°E
120°E
122°E
36°N
34°N
32°N
30°N
28°N
26°N
N
Jiangsu
Anhui
Nanjing
Shanghai
The Yangtze River
Zhejiang
NO2-VCD
(10^15 mol/cm2)
0 - 2.0
2.0 - 3.3
3.3 - 4.7
4.7 - 6.5
6.5 - 9.0
9.0 - 12.0
12.0 - 18.5

Figure S7.

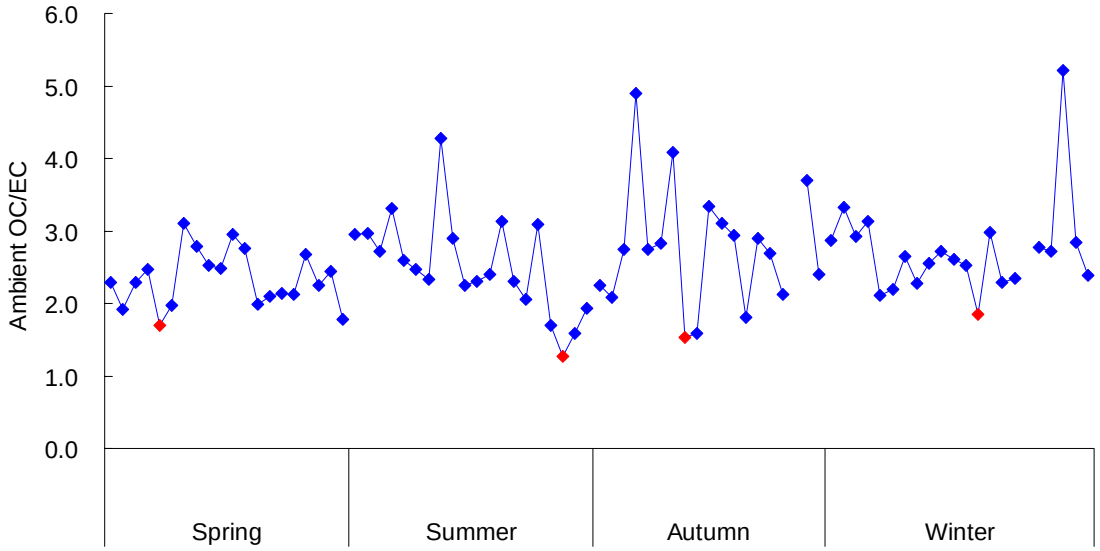


Figure S8.

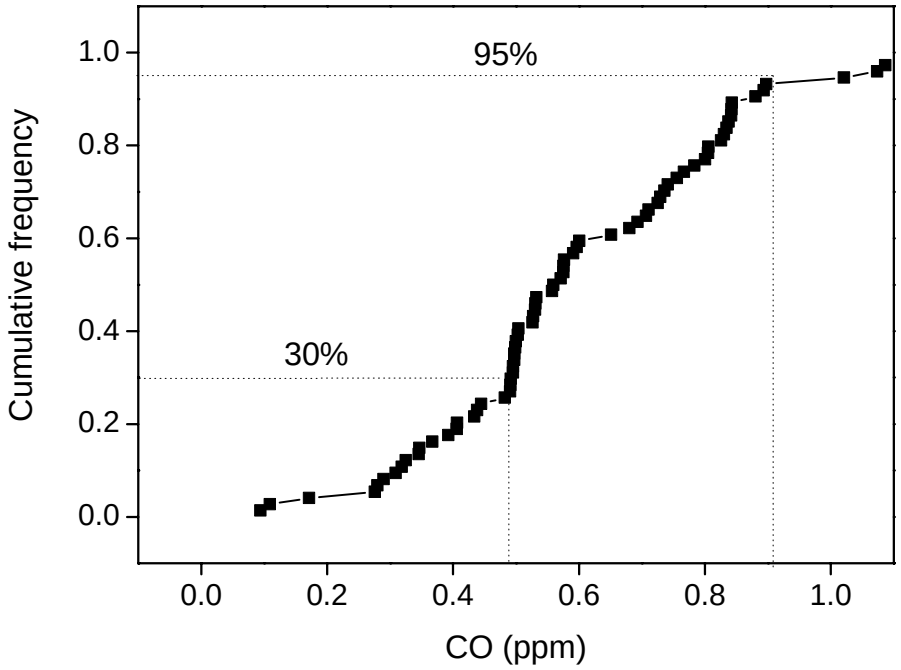


Figure S9.

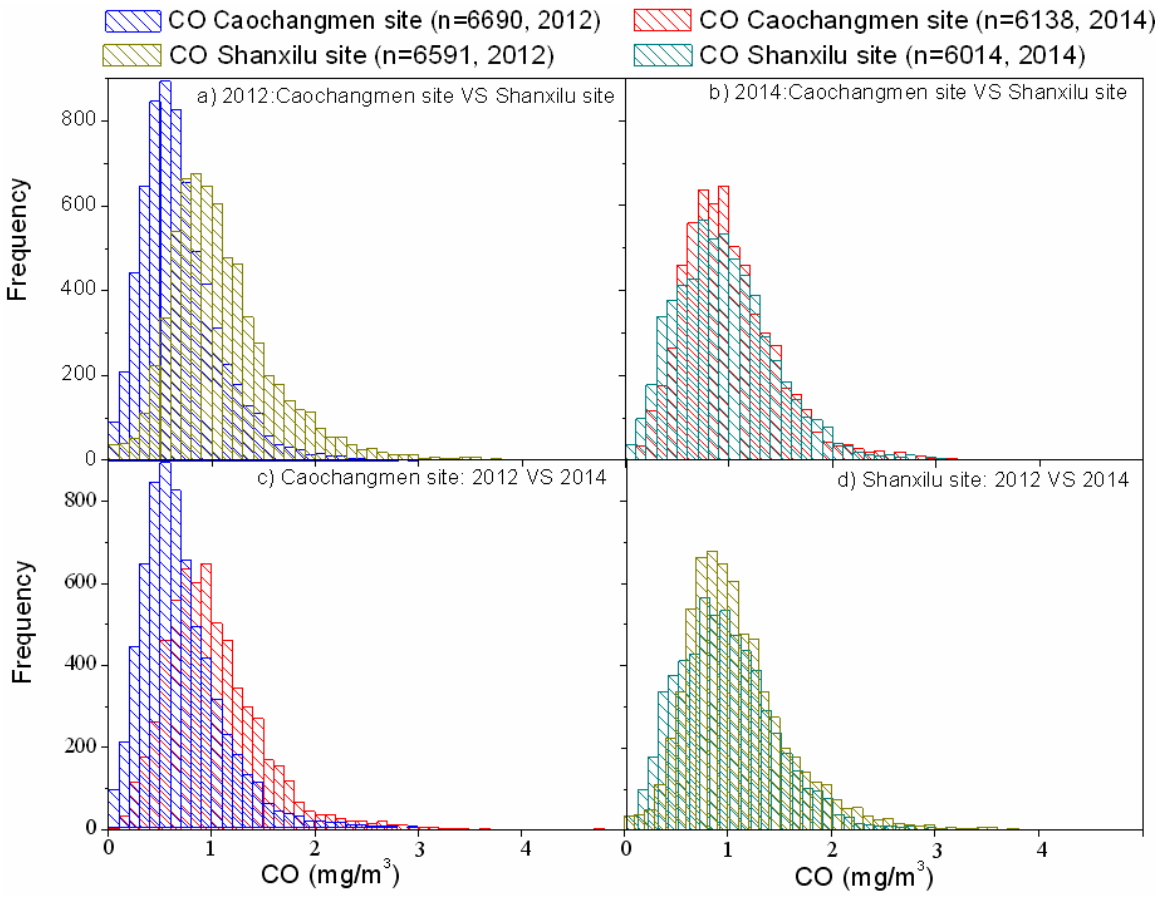
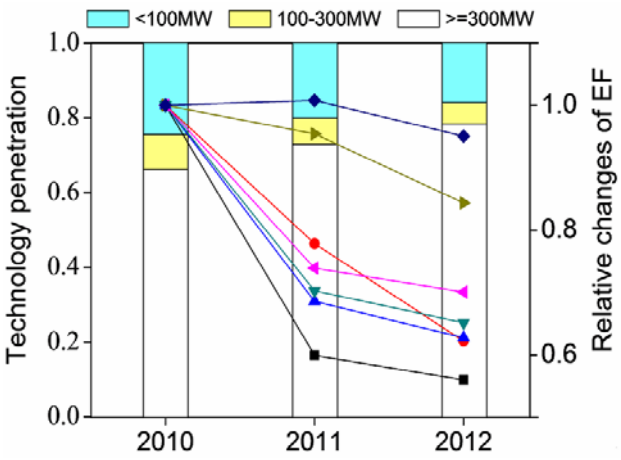
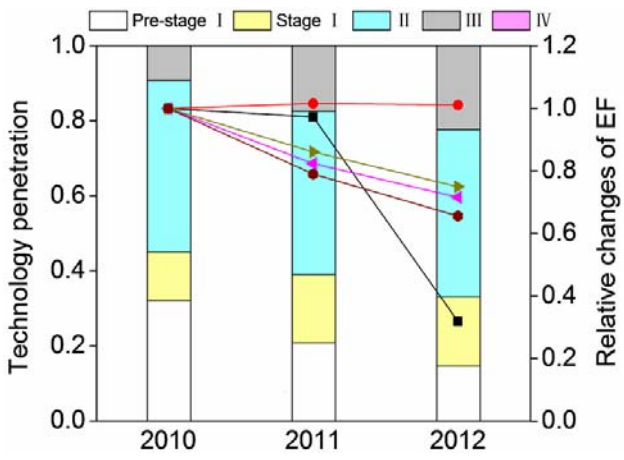

CO Caochangmen site (n=6690, 2012)
CO Shanxilu site (n=6591, 2012)
CO Caochangmen site (n=6138, 2014)
CO Shanxilu site (n=6014, 2014)
a) 2012:Caochangmen site VS Shanxilu site
b) 2014:Caochangmen site VS Shanxilu site
c) Caochangmen site: 2012 VS 2014
d) Shanxilu site: 2012 VS 2014
Frequency
CO (mg/m3)

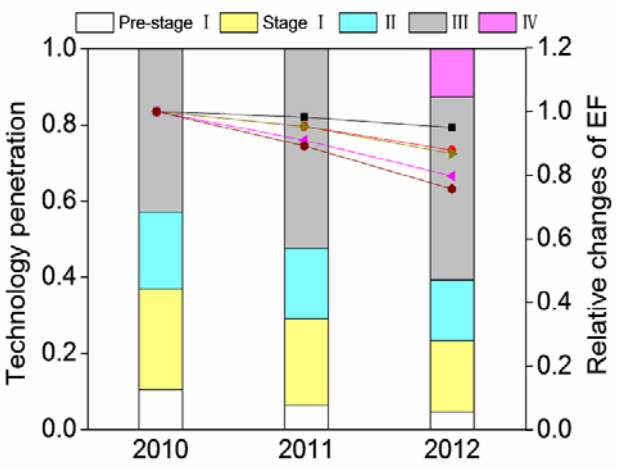
Figure S10.



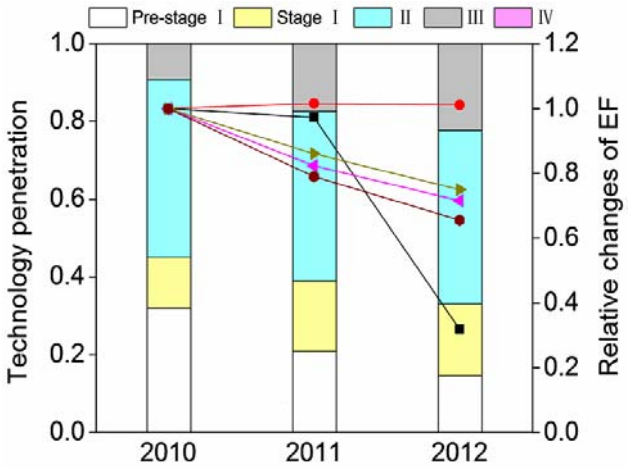
(a) Power plant



(b) Gasoline vehicles



(c) Diesel vehicles



(d) Motocycles

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