
Supplementary information

Increase in domestic electricity consumption from particulate air pollution

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Supplementary Table 1 Descriptive statistics of residential buildings

	N	mean	sd	min	max
Electricity consumption (kWh/day/consumer)	5413932	38.20	28.79	0.00	585.72
PM10 concentration ($\mu\text{g}/\text{m}^3$)	5413475	31.04	16.26	0.00	289.94
PM2.5 concentration ($\mu\text{g}/\text{m}^3$)	5379272	8.07	4.59	0.70	112.78
Ozone concentration (ppm)	5399569	0.05	0.01	0.00	0.08
CDD	5413932	13.02	12.12	0.00	41.58
HDD	5413932	2.34	4.72	0.00	27.69
Precipitation accumulation (inch/day)	5302888	0.03	0.14	0.00	11.60
Wind speed (m/s)	5412866	2.66	0.98	0.21	8.69
Relative humidity	5412866	31.24	16.15	5.17	97.32
Electricity price (\$/kWh)	5413932	0.10	0.02	0.04	0.13
Solar power (AC)	260	6.531673	2.765513	0.7	21.5
Solar power (DC)	260	7.395838	3.466562	0.72	24
Solar electricity generation (kWh/day/consumer)					
Before installation	5200888	0.00	0.00	0.00	0.00
After installation	213044	28.28	15.95	0.00	133.53

Supplementary Table 2 Descriptive statistics of different income and ethnic groups in residential buildings

		N	mean	sd	min	max
Income						
Low	Electricity consumption (kWh/day/consumer)	1979239	35.23	26.40	0.00	385.10
	PM10 concentration ($\mu\text{g}/\text{m}^3$)	1979086	30.83	16.07	0.00	289.94
	PM2.5 concentration ($\mu\text{g}/\text{m}^3$)	1968169	8.12	4.74	0.70	112.78
Medium	Electricity consumption (kWh/day/consumer)	2665377	38.81	27.99	0.00	577.76
	PM10 concentration ($\mu\text{g}/\text{m}^3$)	2665259	31.15	16.37	0.00	272.78
	PM2.5 concentration	2650337	8.05	4.52	0.76	112.78

High	($\mu\text{g}/\text{m}^3$)					
	Electricity consumption (kWh/day/consumer)	565324	48.81	36.71	0.00	520.77
	PM10 concentration ($\mu\text{g}/\text{m}^3$)	565138	31.30	16.46	0.00	272.78
	PM2.5 concentration ($\mu\text{g}/\text{m}^3$)	557754	7.99	4.35	0.76	109.89
Ethnic group						
Asian	Electricity consumption (kWh/day/consumer)	117181	35.34	27.86	0.00	239.19
	PM10 concentration ($\mu\text{g}/\text{m}^3$)	117181	31.67	16.59	3.04	257.51
	PM2.5 concentration ($\mu\text{g}/\text{m}^3$)	117181	8.18	4.61	1.11	112.78
	Electricity consumption (kWh/day/consumer)	808045	38.92	25.84	0.00	334.36
Hispanic	PM10 concentration ($\mu\text{g}/\text{m}^3$)	808045	31.62	16.34	1.81	272.78
	PM2.5 concentration ($\mu\text{g}/\text{m}^3$)	807986	8.24	4.81	0.90	112.78
	Electricity consumption (kWh/day/consumer)	234218	40.13	27.77	0.00	235.00
	PM10 concentration ($\mu\text{g}/\text{m}^3$)	234218	31.51	16.46	2.40	272.78
Other	PM2.5 concentration ($\mu\text{g}/\text{m}^3$)	234137	8.16	4.70	1.11	112.78
	Electricity consumption (kWh/day/consumer)	3570894	38.22	29.53	0.00	585.72
	PM10 concentration ($\mu\text{g}/\text{m}^3$)	3570561	30.92	16.25	0.00	289.94
	PM2.5 concentration ($\mu\text{g}/\text{m}^3$)	3541820	8.02	4.52	0.70	112.78
White	Electricity consumption (kWh/day/consumer)					
	PM10 concentration ($\mu\text{g}/\text{m}^3$)					
	PM2.5 concentration ($\mu\text{g}/\text{m}^3$)					
	Electricity consumption (kWh/day/consumer)					

Supplementary Table 3 Descriptive statistics of commercial buildings

	N	mean	sd	min	max
Electricity consumption (kWh/day/consumer)	21456725	56.24	292.11	0.00	33616.83
PM10 concentration ($\mu\text{g}/\text{m}^3$)	21355597	32.43	17.01	0.00	531.98
PM2.5 concentration ($\mu\text{g}/\text{m}^3$)	21245070	8.12	4.70	0.00	121.12

Ozone concentration (ppm)	21298950	0.05	0.01	0.00	0.09
CDD	21456751	13.01	12.07	0.00	42.03
HDD	21456751	2.22	4.58	0.00	31.30
Precipitation accumulation (inch/day)	21001919	0.02	0.13	0.00	11.60
Wind speed (m/s)	21311836	2.71	0.98	0.00	9.27
Relative humidity	21311842	30.08	15.75	4.34	97.32
Demand charge (\$/kWh)	21433357	4.88	1.15	0.00	7.15
Energy charge (\$/kWh)	21433357	0.08	0.01	0.04	0.17
Solar power (AC)		75.13			
	330		192.78	1.663	2880
Solar power (DC)	330	85.50	204.67	0.9	2880
Solar electricity generation (kWh/day/consumer)					
Before installation	21219912	0.00	0.00	0.00	0.00
After installation	236839	282.12	515.40	0.00	7300.22

Supplementary Table 4 Descriptive statistics of different sectors in commercial buildings

		N	mean	sd	min	max
Sectors						
Others	Electricity consumption (kWh/day/consumer)	14119867	60.08	328.57	0.00	33616.83
	PM10 concentration ($\mu\text{g}/\text{m}^3$)	14037543	32.43	17.03	0.00	531.98
	PM2.5 concentration ($\mu\text{g}/\text{m}^3$)	13964251	8.11	4.69	0.00	121.12
Recreation and service	Electricity consumption (kWh/day/consumer)	5596808	39.20	75.77	0.00	2892.58
	PM10 concentration ($\mu\text{g}/\text{m}^3$)	5580458	32.45	17.01	0.00	491.35
	PM2.5 concentration ($\mu\text{g}/\text{m}^3$)	5549232	8.12	4.70	0.00	121.12
Retail trading	Electricity consumption (kWh/day/consumer)	1740050	79.84	395.04	0.00	10767.71
	PM10 concentration ($\mu\text{g}/\text{m}^3$)	1737596	32.37	16.89	1.81	326.41
	PM2.5 concentration ($\mu\text{g}/\text{m}^3$)	1731587	8.17	4.76	0.65	121.12

Supplementary Table 5 Descriptive statistics of individual coefficients in residential buildings

		N	mean	sd	min	max
Income						
PM10	Low	1255	0.046	0.112	-0.525	0.482
	Medium	1653	0.036	0.112	-0.650	0.623
	High	358	0.030	0.164	-0.423	0.894
PM2.5	Low	1255	0.519	1.174	-4.259	6.754
	Medium	1653	0.370	1.034	-7.743	6.420
	High	358	0.283	1.356	-4.374	7.398
Ethnic group						
PM10	White	2220	0.036	0.121	-0.650	0.894
	Asian	69	0.039	0.126	-0.259	0.296
	Hispanic	511	0.047	0.105	-0.344	0.399
	Other	141	0.040	0.121	-0.463	0.582
PM2.5	White	2220	0.379	1.113	-7.743	7.398
	Asian	69	0.527	1.138	-1.802	2.805
	Hispanic	511	0.520	1.146	-4.139	6.634
	Other	141	0.430	1.160	-3.635	6.754

Notes: The coefficients were obtained from running the instrumental variable regression for individual residential consumers. The coefficients measure the impact of air pollution on individual consumers. We excluded the buildings with records fewer than 3 years which account for 920/3393=27% of the sample.

Supplementary Table 6 Effect of air pollution on electricity consumption in residential buildings, GLS estimation

	(1)	(2)
	GLS	GLS
PM10 concentration	0.022*** (0.001)	
PM2.5 concentration		0.093*** (0.004)
Ozone concentration	58.917*** (1.633)	58.252*** (1.616)
Heating degree days	0.780*** (0.012)	0.757*** (0.012)
Cooling degree days	1.103*** (0.009)	1.107*** (0.009)
Precipitation accumulation	-0.135** (0.068)	-0.048 (0.068)
Wind speed	-0.121*** (0.015)	0.023* (0.013)
Relative humidity	0.044*** (0.001)	0.037*** (0.001)

Daily electricity price (log)	-8.002***	-8.045***
	(0.819)	(0.821)
Constant	-0.256	-0.596
	(2.116)	(2.121)
Fixed effects		
Consumer	Y	Y
Weekend	Y	Y
Holiday	Y	Y
Month-of-year	Y	Y
Year	Y	Y
N	5288247	5274683
R ²	0.507	0.507

Notes: Standard errors in parentheses are clustered to building unit level. * p<0.1, ** p<0.05, *** p<0.01.

Supplementary Table 7 Effect of air pollution on electricity consumption in commercial buildings, GLS estimation

	(1)	(2)
	GLS	GLS
PM10 concentration	0.053***	
	(0.005)	
PM2.5 concentration		0.079***
		(0.016)
Ozone concentration	13.839***	12.071***
	(4.133)	(4.224)
Heating degree days	0.144***	0.107***
	(0.024)	(0.025)
Cooling degree days	0.716***	0.731***
	(0.024)	(0.024)
Precipitation accumulation	-0.795***	-0.866***
	(0.117)	(0.115)
Wind speed	0.656***	0.827***
	(0.037)	(0.031)
Relative humidity	0.062***	0.042***
	(0.004)	(0.004)
Demand charge (log)	77.546***	77.700***
	(27.337)	(27.378)
Energy charge (log)	26.434***	26.500***
	(10.191)	(10.215)
Constant	-1.334	0.205
	(33.387)	(33.576)
Fixed effects		
Building	Y	Y
Weekend	Y	Y

Holiday	Y	Y
Month-of-year	Y	Y
Year	Y	Y
N	20804874	20774282
R ²	0.013	0.013

Notes: Standard errors in parentheses are clustered to building unit level. * p<0.1, ** p<0.05, *** p<0.01.

Supplementary Table 8 Effect of air pollution on solar energy generation in residential buildings, GLS estimation

	(1)	(2)
	GLS	GLS
PM10 concentration	-0.003* (0.002)	
PM2.5 concentration		-0.029** (0.014)
Heating degree days	0.119*** (0.010)	0.124*** (0.011)
Cooling degree days	0.103*** (0.009)	0.102*** (0.008)
Precipitation accumulation	-1.957*** (0.286)	-1.950*** (0.287)
Wind speed	-0.777*** (0.045)	-0.818*** (0.045)
Daily electricity price (log)	-0.573 (0.765)	-0.581 (0.769)
Surface albedo	81.925*** (14.881)	80.756*** (14.722)
Constant	4.474 (3.203)	4.896 (3.177)
Fixed effects		
Building	Y	Y
Weekend	Y	Y
Holiday	Y	Y
Month-of-year	Y	Y
Year	Y	Y
N	199822	198647
R ²	0.388	0.389

Notes: Standard errors in parentheses are clustered to building unit level. * p<0.1, ** p<0.05, *** p<0.01.

Supplementary Table 9 Effect of air pollution on solar energy generation in commercial buildings, GLS estimation

	(1)	(2)
	GLS	GLS
PM10 concentration	-0.013***	

	(0.002)	
PM2.5 concentration		-0.038*** (0.005)
Heating degree days	-0.028*** (0.005)	-0.011*** (0.004)
Cooling degree days	0.028*** (0.003)	0.025*** (0.003)
Precipitation accumulation	-0.543*** (0.075)	-0.415*** (0.067)
Wind speed	0.092*** (0.015)	0.037*** (0.010)
Demand charge (log)	1.376* (0.757)	1.484* (0.760)
Energy charge (log)	-2.159*** (0.501)	-2.060*** (0.497)
Surface albedo	45.018*** (5.571)	41.725*** (5.284)
Constant	-13.289*** (2.917)	-12.589*** (2.876)
Fixed effects		
Building	Y	Y
Weekend	Y	Y
Holiday	Y	Y
Month-of-year	Y	Y
Year	Y	Y
N	19661895	19631914
R ²	0.001	0.001

Notes: Standard errors in parentheses are clustered to building unit level. * p<0.1, ** p<0.05, *** p<0.01.

Supplementary Table 10 Effect of air pollution on electricity consumption in commercial buildings, buildings with maximum daily electricity consumption over 500kWh dropped

	(1) GLS	(2) IV	(3) IV	(4) GLS	(5) IV	(6) IV
Wind cosine		13.707*** (0.009)			2.149*** (0.005)	
PM10 concentration	0.039*** (0.001)		0.030*** (0.004)			
PM2.5 concentration				0.089*** (0.004)		0.191*** (0.027)
Heating degree days	7.178*** (1.262)	-7.267*** (0.568)	6.721*** (1.261)	6.090*** (1.261)	-4.805*** (0.143)	7.190*** (1.256)
Cooling degree days	0.105*** (0.006)	-0.546*** (0.001)	0.099*** (0.007)	0.075*** (0.006)	0.081*** (0.000)	0.067*** (0.007)
Precipitation	0.497*** (0.009)	0.214*** (0.001)	0.500*** (0.009)	0.508*** (0.009)	0.007*** (0.000)	0.506*** (0.009)
Wind speed	-0.863*** (0.055)	-3.790*** (0.029)	-0.898*** (0.061)	-0.866*** (0.056)	-1.669*** (0.016)	-0.695*** (0.079)
Dust storm	0.518*** (0.016)	1.029*** (0.005)	0.530*** (0.017)	0.683*** (0.016)	-1.309*** (0.002)	0.811*** (0.038)
Demand charge (log)	0.041*** (0.001)	-0.454*** (0.001)	0.037*** (0.002)	0.027*** (0.001)	-0.027*** (0.000)	0.029*** (0.001)
Energy charge (log)	51.731*** (5.087)	0.368*** (0.130)	51.735*** (5.087)	51.738*** (5.088)	0.038 (0.029)	51.734*** (5.087)
Solar irradiance	6.343*** (0.500)	0.377*** (0.083)	6.348*** (0.500)	6.351*** (0.502)	0.096*** (0.014)	6.341*** (0.502)
Constant	-28.556*** (7.789)			-27.823*** (7.790)		
Fixed effect						
Building	Y	Y	Y	Y	Y	Y
Weekend	Y	Y	Y	Y	Y	Y
Holiday	Y	Y	Y	Y	Y	Y
Month-of-year	Y	Y	Y	Y	Y	Y

Year	Y	Y	Y	Y	Y	Y
N	17469689	17467294	17467294	17445095	17444152	17444152
R ²	0.101		0.101	0.101		0.100

Notes: Standard errors in parentheses are clustered to building unit level. * p<0.1, ** p<0.05, *** p<0.01.

Supplementary Table 11 Effect of air pollution on electricity consumption in commercial buildings, buildings with maximum daily electricity consumption over 1000kWh dropped

	(1) GLS	(2) IV	(3) IV	(4) GLS	(5) IV	(6) IV
Wind cosine		13.717*** (0.009)			2.150*** (0.005)	
PM10 concentration	0.042*** (0.001)		0.031*** (0.005)			
PM2.5 concentration				0.092*** (0.005)		0.193*** (0.032)
Heating degree days	7.605*** (1.550)	-7.871*** (0.550)	7.004*** (1.545)	6.472*** (1.543)	-4.963*** (0.139)	7.566*** (1.531)
Cooling degree days	0.086*** (0.007)	-0.548*** (0.001)	0.079*** (0.008)	0.054*** (0.007)	0.081*** (0.000)	0.047*** (0.008)
Precipitation	0.577*** (0.011)	0.214*** (0.001)	0.580*** (0.011)	0.588*** (0.011)	0.007*** (0.000)	0.586*** (0.011)
Wind speed	-0.873*** (0.069)	-3.787*** (0.028)	-0.919*** (0.075)	-0.881*** (0.070)	-1.665*** (0.015)	-0.714*** (0.095)
Dust storm	0.606*** (0.020)	1.026*** (0.005)	0.622*** (0.020)	0.780*** (0.018)	-1.311*** (0.002)	0.906*** (0.044)
Demand charge (log)	0.047*** (0.001)	-0.454*** (0.001)	0.042*** (0.002)	0.031*** (0.001)	-0.027*** (0.000)	0.033*** (0.001)
Energy charge (log)	60.742*** (6.086)	0.311** (0.130)	60.746*** (6.086)	60.747*** (6.087)	0.023 (0.028)	60.745*** (6.086)
Solar irradiance	7.677*** (0.590)	0.359*** (0.080)	7.683*** (0.590)	7.683*** (0.591)	0.088*** (0.014)	7.674*** (0.591)
Constant	-34.407***			-33.570***		

	(9.353)		(9.354)			
Fixed effect						
Building	Y	Y	Y	Y	Y	Y
Weekend	Y	Y	Y	Y	Y	Y
Holiday	Y	Y	Y	Y	Y	Y
Month-of-year	Y	Y	Y	Y	Y	Y
Year	Y	Y	Y	Y	Y	Y
N	18740142	18737533	18737533	18713403	18712394	18712394
R ²	0.090		0.090	0.089		0.089

Notes: Standard errors in parentheses are clustered to building unit level. * p<0.1, ** p<0.05, *** p<0.01.

Supplementary Table 12 Effect of air pollution on electricity consumption in residential buildings by season, IV estimation

	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
	Winter	Winter	Winter	Winter	Summer	Summer	Summer	Summer	Summer peak	Summer peak	Summer peak	Summer peak
Wind cosine	20.157*** (0.024)		2.494*** (0.013)		6.385*** (0.033)		0.729*** (0.006)		5.356*** (0.041)		0.987*** (0.004)	
PM10 concentration		0.000 (0.002)				0.104*** (0.009)				0.178*** (0.015)		
PM2.5 concentration				0.001 (0.015)				0.904*** (0.077)				0.960*** (0.083)
Ozone concentration	-398.664** * (1.103)	-4.129** (1.895)	87.693** * (0.255)	-4.378** (2.133)	206.567** * (0.706)	59.163** * (2.645)	70.496** * (0.155)	16.870** * (5.599)	151.850** * (0.608)	65.715** * (3.214)	40.516** * (0.086)	53.762** * (4.082)
Heating degree days	-0.379*** (0.001)	0.718*** (0.011)	0.151*** (0.001)	0.716*** (0.012)	1.029*** (0.016)	1.810*** (0.041)	-0.299*** (0.002)	2.195*** (0.053)	0.000 (.)	0.000 (.)	0.000 (.)	0.000 (.)
Cooling degree days	-0.139*** (0.001)	0.422*** (0.008)	-0.018*** (0.000)	0.422*** (0.008)	0.149*** (0.002)	1.358*** (0.011)	0.013*** (0.000)	1.362*** (0.011)	1.763*** (0.004)	1.711*** (0.032)	0.230*** (0.000)	1.803*** (0.026)
Precipitation	-7.109***	-1.236***	-5.882***	-1.235***	-0.951***	-0.375***	-0.253***	-0.243***	0.158***	0.929***	0.380***	0.605***

	(0.033)	(0.071)	(0.011)	(0.122)	(0.033)	(0.080)	(0.011)	(0.079)	(0.020)	(0.080)	(0.005)	(0.087)
Wind speed	0.161***	-0.099***	-1.771***	-0.096***	4.702***	-0.678***	0.091***	-0.269***	2.497***	-0.687***	-0.245***	-0.009
	(0.008)	(0.009)	(0.004)	(0.028)	(0.013)	(0.044)	(0.002)	(0.019)	(0.020)	(0.049)	(0.001)	(0.034)
Relative humidity	-0.517***	-0.023***	-0.033***	-0.024***	-0.470***	0.217***	-0.018***	0.185***	0.068***	0.259***	0.068***	0.205***
	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.005)	(0.000)	(0.003)	(0.001)	(0.004)	(0.000)	(0.007)
Daily electricity price (log)	-0.034	11.285**	0.081	11.286**	2.606***	-4.672***	0.554***	-4.890***	0.589***	-4.141***	-0.800***	-3.277***
	(0.227)	(1.030)	(0.089)	(1.033)	(0.086)	(0.376)	(0.015)	(0.377)	(0.069)	(0.343)	(0.017)	(0.361)
Fixed effects												
Consumer	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Weekend	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Holiday	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Month-of-year	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
N	2566703	2566703	2560063	2560063	1803494	1803494	1798776	1798776	917788	917788	915760	915760
R ²		0.150		0.150		0.467		0.462		0.183		0.209

Notes: Winter months are January-April, November, and December; summer peak months are July and August; regular summer months are May, June, September, and October. Standard errors in parentheses are clustered to building unit level. * p<0.1, ** p<0.05, *** p<0.01.

Supplementary Table 13 Effect of air pollution on total trips per person at county level

	(1) GLS	(2) IV	(3) IV	(4) GLS	(5) IV	(6) IV
Wind cosine		-4.551*** (0.141)			-1.614*** (0.047)	
PM10 concentration	0.001*** (0.000)		-0.023*** (0.001)			
PM2.5 concentration				-0.005*** (0.000)		-0.071*** (0.003)
Ozone concentration	-0.848*** (0.164)	-155.829*** (8.628)	-4.812*** (0.398)	-1.021*** (0.145)	-51.899*** (1.970)	-4.251*** (0.300)
Heating degree days	-0.004*** (0.000)	-0.085*** (0.004)	-0.007*** (0.000)	-0.004*** (0.000)	0.027*** (0.001)	-0.003*** (0.000)
Cooling degree days	0.003*** (0.001)	0.682*** (0.050)	0.018*** (0.002)	0.006*** (0.001)	0.120*** (0.018)	0.018*** (0.002)
Precipitation	-0.000 (0.000)	-0.090*** (0.004)	-0.003*** (0.000)	-0.001*** (0.000)	-0.103*** (0.002)	-0.008*** (0.000)
Wind speed	-0.025*** (0.001)	-1.251*** (0.030)	-0.054*** (0.002)	-0.030*** (0.001)	-0.822*** (0.008)	-0.083*** (0.003)
Relative humidity	-0.004*** (0.000)	-0.150*** (0.004)	-0.007*** (0.000)	-0.003*** (0.000)	0.023*** (0.001)	-0.002*** (0.000)
Constant	3.177*** (0.012)			3.245*** (0.010)		
Fixed effect						
County	Y	Y	Y	Y	Y	Y
Month	Y	Y	Y	Y	Y	Y
Day-of-week	Y	Y	Y	Y	Y	Y
N	85713	52998	52998	117271	74110	74110
R ²	0.567		0.382	0.566		0.378

Notes: Standard errors in parentheses are clustered to building unit level. * p<0.1, ** p<0.05, *** p<0.01.

Supplementary Table 14 Effect of air pollution on work trips per person at county level

	(1) GLS	(2) IV	(3) IV	(4) GLS	(5) IV	(6) IV
Wind cosine		-4.551*** (0.141)			-1.614*** (0.047)	
PM10 concentration	0.000 (0.000)		-0.010*** (0.001)			
PM2.5 concentration				-0.001*** (0.000)		-0.027*** (0.001)
Ozone concentration	0.340*** (0.064)	-155.829*** (8.628)	-1.376*** (0.157)	0.303*** (0.055)	-51.899*** (1.970)	-1.049*** (0.112)
Heating degree days	-0.000*** (0.000)	-0.085*** (0.004)	-0.002*** (0.000)	-0.000*** (0.000)	0.027*** (0.001)	-0.000*** (0.000)
Cooling degree days	-0.001*** (0.000)	0.682*** (0.050)	0.006*** (0.001)	-0.001*** (0.000)	0.120*** (0.018)	0.003*** (0.001)
Precipitation	-0.000*** (0.000)	-0.090*** (0.004)	-0.001*** (0.000)	-0.000*** (0.000)	-0.103*** (0.002)	-0.003*** (0.000)
Wind speed	-0.003*** (0.000)	-1.251*** (0.030)	-0.015*** (0.001)	-0.005*** (0.000)	-0.822*** (0.008)	-0.026*** (0.001)
Relative humidity	-0.000*** (0.000)	-0.150*** (0.004)	-0.002*** (0.000)	-0.000*** (0.000)	0.023*** (0.001)	0.000*** (0.000)
Constant	0.256*** (0.006)			0.282*** (0.004)		
Fixed effect						
County	Y	Y	Y	Y	Y	Y
Month	Y	Y	Y	Y	Y	Y
Day-of-week	Y	Y	Y	Y	Y	Y
N	85713	52998	52998	117271	74110	74110
R ²	0.612		0.404	0.609		0.454

Notes: Standard errors in parentheses are clustered to building unit level. * p<0.1, ** p<0.05, *** p<0.01.

Supplementary Table 15 Effect of air pollution on non-work trips per person at county level

	(1)	(2)	(3)	(4)	(5)	(6)
	GLS	IV	IV	GLS	IV	IV
Wind cosine		-4.551*** (0.141)			-1.614*** (0.047)	
PM10 concentration	0.000 (0.000)		-0.010*** (0.001)			
PM2.5 concentration				-0.001*** (0.000)		-0.027*** (0.001)
Ozone concentration	0.340*** (0.064)	-155.829*** (8.628)	-1.376*** (0.157)	0.303*** (0.055)	-51.899*** (1.970)	-1.049*** (0.112)
Heating degree days	-0.000*** (0.000)	-0.085*** (0.004)	-0.002*** (0.000)	-0.000*** (0.000)	0.027*** (0.001)	-0.000*** (0.000)
Cooling degree days	-0.001*** (0.000)	0.682*** (0.050)	0.006*** (0.001)	-0.001*** (0.000)	0.120*** (0.018)	0.003*** (0.001)
Precipitation	-0.000*** (0.000)	-0.090*** (0.004)	-0.001*** (0.000)	-0.000*** (0.000)	-0.103*** (0.002)	-0.003*** (0.000)
Wind speed	-0.003*** (0.000)	-1.251*** (0.030)	-0.015*** (0.001)	-0.005*** (0.000)	-0.822*** (0.008)	-0.026*** (0.001)
Relative humidity	-0.000*** (0.000)	-0.150*** (0.004)	-0.002*** (0.000)	-0.000*** (0.000)	0.023*** (0.001)	0.000*** (0.000)
Constant	0.256*** (0.006)			0.282*** (0.004)		
Fixed effect						
County	Y	Y	Y	Y	Y	Y
Month	Y	Y	Y	Y	Y	Y
Day-of-week	Y	Y	Y	Y	Y	Y
N	85713	52998	52998	117271	74110	74110
R ²	0.612		0.404	0.609		0.454

Notes: Standard errors in parentheses are clustered to building unit level. * p<0.1, ** p<0.05, *** p<0.01.

Supplementary Table 16 Effect of air pollution on electricity consumption in residential buildings, IDW within 10km

	(1) GLS	(2) IV	(3) IV	(4) GLS	(5) IV	(6) IV
Wind cosine		10.476*** (0.031)			2.524*** (0.018)	
PM10 concentration	0.024*** (0.002)		0.074*** (0.015)			
PM2.5 concentration				0.048*** (0.011)		0.243*** (0.062)
Ozone concentration	80.107*** (3.601)	5.222*** (1.255)	80.720*** (3.668)	74.116*** (3.124)	-0.068 (0.367)	74.996*** (3.228)
Heating degree days	0.753*** (0.028)	-0.260*** (0.003)	0.768*** (0.028)	0.764*** (0.026)	0.137*** (0.002)	0.739*** (0.027)
Cooling degree days	1.004*** (0.020)	0.174*** (0.003)	0.991*** (0.019)	0.995*** (0.020)	0.023*** (0.001)	0.987*** (0.019)
Precipitation	-0.554*** (0.102)	-3.967*** (0.034)	-0.340*** (0.119)	-0.425*** (0.106)	-2.520*** (0.009)	0.080 (0.196)
Wind speed	-0.008 (0.019)	0.761*** (0.013)	-0.049** (0.023)	0.082*** (0.018)	-0.974*** (0.006)	0.267*** (0.063)
Relative humidity	0.054*** (0.002)	-0.330*** (0.002)	0.069*** (0.005)	0.048*** (0.002)	0.002*** (0.001)	0.046*** (0.002)
Daily electricity price (log)	-2.960 (1.949)	0.590*** (0.191)	-2.985 (1.949)	-2.581 (1.857)	0.603*** (0.073)	-2.695 (1.856)
Constant	11.674** (4.993)			12.139** (4.771)		
Fixed effect						
Building	Y	Y	Y	Y	Y	Y
Weekend	Y	Y	Y	Y	Y	Y
Holiday	Y	Y	Y	Y	Y	Y
Month-of-year	Y	Y	Y	Y	Y	Y

Year	Y	Y	Y	Y	Y	Y
N	1103915	1103915	1103915	1048126	1048126	1048126
R ²	0.480		0.479	0.494		0.493

Notes: Standard errors in parentheses are clustered to building unit level. * p<0.1, ** p<0.05, *** p<0.01.

Supplementary Table 17 Effect of air pollution on electricity consumption in commercial buildings, IDW within 10km

	(1) GLS	(2) IV	(3) IV	(4) GLS	(5) IV	(6) IV
Wind cosine		9.987*** (0.019)			2.721*** (0.008)	
PM10 concentration	0.069*** (0.007)		0.053 (0.036)			
PM2.5 concentration				0.171*** (0.022)		0.151 (0.134)
Ozone concentration	-6.906 (7.505)	-28.760*** (1.091)	-7.826 (8.475)	-8.724 (7.818)	-7.175*** (0.230)	-9.036 (8.551)
Heating degree days	0.118*** (0.024)	-0.458*** (0.002)	0.110*** (0.025)	0.082*** (0.021)	0.082*** (0.001)	0.084*** (0.025)
Cooling degree days	0.688*** (0.034)	0.219*** (0.001)	0.692*** (0.035)	0.698*** (0.036)	0.018*** (0.000)	0.699*** (0.035)
Precipitation	-0.695*** (0.171)	-3.405*** (0.022)	-0.749*** (0.248)	-0.456** (0.191)	-2.258*** (0.007)	-0.496 (0.403)
Wind speed	0.615*** (0.032)	0.497*** (0.009)	0.624*** (0.040)	0.835*** (0.040)	-1.116*** (0.004)	0.814*** (0.148)
Relative humidity	0.062*** (0.007)	-0.353*** (0.001)	0.056*** (0.013)	0.040*** (0.005)	-0.014*** (0.000)	0.040*** (0.005)
Demand charge (log)	60.497*** (14.721)	0.107 (0.382)	60.499*** (14.721)	61.226*** (14.972)	0.026 (0.071)	61.227*** (14.971)
Energy charge (log)	23.216 (16.676)	0.541*** (0.155)	23.226 (16.682)	23.424 (17.161)	0.080** (0.039)	23.427 (17.163)

Constant	16.320 (36.450)			15.957 (37.600)		
Fixed effect						
Building	Y	Y	Y	Y	Y	Y
Weekend	Y	Y	Y	Y	Y	Y
Holiday	Y	Y	Y	Y	Y	Y
Month-of-year	Y	Y	Y	Y	Y	Y
Year	Y	Y	Y	Y	Y	Y
N	5037242	5036861	5036861	4880457	4880202	4880202
R ²	0.032		0.032	0.031		0.031

Notes: Standard errors in parentheses are clustered to building unit level. * p<0.1, ** p<0.05, *** p<0.01.

Supplementary Table 18 Effect of air pollution on solar energy generation in residential buildings, IDW within 10km

	(1) GLS	(2) IV	(3) IV	(4) GLS	(5) IV	(6) IV
Wind cosine		8.020*** (0.183)			2.827*** (0.076)	
PM10 concentration	0.001 (0.005)		-0.201*** (0.031)			
PM2.5 concentration				-0.021 (0.031)		-0.567*** (0.087)
Heating degree days	0.081*** (0.020)	-0.486*** (0.012)	-0.021 (0.022)	0.083*** (0.018)	0.058*** (0.010)	0.111*** (0.020)
Cooling degree days	0.033*** (0.011)	0.441*** (0.015)	0.129*** (0.020)	0.034*** (0.010)	0.016*** (0.003)	0.049*** (0.011)
Precipitation	-3.184*** (0.340)	-13.885*** (0.436)	-5.775*** (0.520)	-3.182*** (0.346)	-2.541*** (0.115)	-4.366*** (0.381)
Wind speed	-0.512*** (0.057)	0.266*** (0.085)	-0.438*** (0.058)	-0.535*** (0.061)	-0.973*** (0.031)	-1.048*** (0.105)
Daily electricity price (log)	-0.260	1.482	-0.001	-0.256	0.969***	0.236

	(1.505)	(1.204)	(1.520)	(1.505)	(0.293)	(1.489)
Solar irradiance	88.654***	752.009***	256.621***	89.486***	5.385	107.522***
	(20.872)	(20.450)	(35.686)	(20.654)	(8.086)	(20.945)
Constant	-1.889			-1.734		
	(5.980)			(6.020)		
Fixed effect						
Building	Y	Y	Y	Y	Y	Y
Weekend	Y	Y	Y	Y	Y	Y
Holiday	Y	Y	Y	Y	Y	Y
Month-of-year	Y	Y	Y	Y	Y	Y
Year	Y	Y	Y	Y	Y	Y
N	30893	30893	30893	30776	30776	30776
R ²	0.443		0.312	0.443		0.397

Notes: Standard errors in parentheses are clustered to building unit level. * p<0.1, ** p<0.05, *** p<0.01.

Supplementary Table 19 Effect of air pollution on solar energy generation in commercial buildings, IDW within 10km

	(1)	(2)	(3)	(4)	(5)	(6)
	GLS	IV	IV	GLS	IV	IV
Wind cosine		6.062***			2.403***	
		(0.038)			(0.009)	
PM10 concentration	-0.006***		-0.027			
	(0.001)		(0.023)			
PM2.5 concentration				-0.015***		-0.085
				(0.004)		(0.055)
Heating degree days	-0.033**	-0.270***	-0.039**	-0.023**	0.272***	-0.005
	(0.013)	(0.002)	(0.018)	(0.012)	(0.001)	(0.006)
Cooling degree days	0.025***	0.142***	0.028***	0.024***	-0.012***	0.023***
	(0.005)	(0.003)	(0.007)	(0.005)	(0.001)	(0.005)
Precipitation	-0.318**	-20.118***	-0.744	-0.227	-3.761***	-0.474
	(0.156)	(0.067)	(0.593)	(0.177)	(0.014)	(0.362)
Wind speed	0.016	-0.281***	0.011	0.002	-1.170***	-0.079

	(0.013)	(0.012)	(0.017)	(0.015)	(0.004)	(0.075)
Demand charge (log)	2.285	-6.694***	2.136	2.422	0.429***	2.447
	(2.456)	(0.176)	(2.305)	(2.533)	(0.048)	(2.551)
Energy charge (log)	-2.603*	-13.820***	-2.896	-2.727*	-2.452***	-2.889*
	(1.530)	(0.476)	(1.818)	(1.564)	(0.105)	(1.677)
Solar irradiance	33.892***	232.102***	39.429***	28.015***	-36.894***	26.010***
	(8.487)	(1.502)	(7.967)	(6.168)	(0.332)	(6.828)
Constant	-14.404*			-14.016*		
	(7.562)			(7.740)		
Fixed effect						
Building	Y	Y	Y	Y	Y	Y
Weekend	Y	Y	Y	Y	Y	Y
Holiday	Y	Y	Y	Y	Y	Y
Month-of-year	Y	Y	Y	Y	Y	Y
Year	Y	Y	Y	Y	Y	Y
N	4765929	4765552	4765552	4616255	4616004	4616004
R ²	0.001		0.001	0.001		0.001

Notes: Standard errors in parentheses are clustered to building unit level. * p<0.1, ** p<0.05, *** p<0.01.

Supplementary Table 20 Effect of air pollution on electricity consumption in residential buildings, IDW within 20km

	(1)	(2)	(3)	(4)	(5)	(6)
	GLS	IV	IV	GLS	IV	IV
Wind cosine		11.867***			1.779***	
		(0.028)			(0.014)	
PM10 concentration	0.017***		0.028***			
	(0.002)		(0.010)			
PM2.5 concentration				0.061***		0.204***
				(0.005)		(0.066)
Ozone concentration	52.415***	-32.964***	52.991***	51.003***	-12.595***	53.248***
	(2.062)	(1.109)	(2.012)	(2.004)	(0.264)	(2.073)
Heating degree days	0.838***	-0.324***	0.842***	0.818***	0.163***	0.795***

	(0.014)	(0.002)	(0.014)	(0.014)	(0.001)	(0.017)
Cooling degree days	1.058***	0.112***	1.056***	1.062***	0.006***	1.059***
	(0.010)	(0.002)	(0.011)	(0.010)	(0.000)	(0.010)
Precipitation	-0.573***	-2.773***	-0.540***	-0.534***	-1.471***	-0.317***
	(0.052)	(0.050)	(0.064)	(0.054)	(0.029)	(0.119)
Wind speed	-0.049***	0.674***	-0.058***	0.037***	-1.210***	0.206**
	(0.015)	(0.013)	(0.015)	(0.014)	(0.004)	(0.083)
Relative humidity	0.042***	-0.401***	0.046***	0.038***	-0.026***	0.040***
	(0.002)	(0.001)	(0.003)	(0.001)	(0.000)	(0.002)
Daily electricity price (log)	-4.595***	-1.255***	-4.580***	-4.721***	0.529***	-4.794***
	(0.938)	(0.192)	(0.938)	(0.944)	(0.039)	(0.946)
Constant	8.570***			8.255***		
	(2.411)			(2.425)		
Fixed effect						
Building	Y	Y	Y	Y	Y	Y
Weekend	Y	Y	Y	Y	Y	Y
Holiday	Y	Y	Y	Y	Y	Y
Month-of-year	Y	Y	Y	Y	Y	Y
Year	Y	Y	Y	Y	Y	Y
N	3489805	3489805	3489805	3441017	3441017	3441017
R ²	0.524		0.524	0.528		0.528

Notes: Standard errors in parentheses are clustered to building unit level. * p<0.1, ** p<0.05, *** p<0.01.

Supplementary Table 21 Effect of air pollution on electricity consumption in commercial buildings, IDW within 20km

	(1)	(2)	(3)	(4)	(5)	(6)
	GLS	IV	IV	GLS	IV	IV
Wind cosine		11.807*** (0.020)			2.251*** (0.009)	
PM10 concentration	0.059*** (0.006)		-0.022 (0.022)			

PM2.5 concentration				0.100*** (0.025)		-0.095 (0.105)
Ozone concentration	-4.648 (5.068)	-43.032*** (0.823)	-10.687* (5.513)	-11.110** (5.120)	-14.664*** (0.199)	-15.158** (5.910)
Heating degree days	0.164*** (0.023)	-0.516*** (0.002)	0.119*** (0.021)	0.118*** (0.024)	0.100*** (0.000)	0.136*** (0.029)
Cooling degree days	0.762*** (0.033)	0.176*** (0.001)	0.783*** (0.035)	0.782*** (0.033)	0.008*** (0.000)	0.787*** (0.034)
Precipitation	-0.507*** (0.172)	-2.696*** (0.026)	-0.723*** (0.185)	-0.498*** (0.181)	-1.388*** (0.018)	-0.766*** (0.241)
Wind speed	0.585*** (0.046)	0.463*** (0.008)	0.638*** (0.052)	0.730*** (0.035)	-1.246*** (0.002)	0.493*** (0.119)
Relative humidity	0.059*** (0.005)	-0.421*** (0.001)	0.028*** (0.008)	0.039*** (0.005)	-0.028*** (0.000)	0.035*** (0.005)
Demand charge (log)	140.089*** (28.367)	0.728*** (0.208)	140.146*** (28.370)	141.633*** (28.774)	0.105** (0.047)	141.653*** (28.777)
Energy charge (log)	33.000*** (10.115)	0.807*** (0.134)	33.067*** (10.122)	33.544*** (10.282)	0.121*** (0.020)	33.569*** (10.286)
Constant	-71.896** (33.578)			-71.200** (34.147)		
Fixed effect						
Building	Y	Y	Y	Y	Y	Y
Weekend	Y	Y	Y	Y	Y	Y
Holiday	Y	Y	Y	Y	Y	Y
Month-of-year	Y	Y	Y	Y	Y	Y
Year	Y	Y	Y	Y	Y	Y
N	12489816	12489402	12489402	12153714	12153448	12153448
R ²	0.021		0.021	0.021		0.021

Notes: Standard errors in parentheses are clustered to building unit level. * p<0.1, ** p<0.05, *** p<0.01.

Supplementary Table 22 Effect of air pollution on solar energy generation in residential buildings, IDW within 20km

	(1) GLS	(2) IV	(3) IV	(4) GLS	(5) IV	(6) IV
Wind cosine		7.079*** (0.215)			1.784*** (0.100)	
PM10 concentration	-0.003 (0.004)		-0.282*** (0.050)			
PM2.5 concentration				-0.022 (0.022)		-1.053*** (0.203)
Heating degree days	0.122*** (0.015)	-0.579*** (0.015)	-0.040 (0.026)	0.126*** (0.016)	0.069*** (0.004)	0.196*** (0.026)
Cooling degree days	0.100*** (0.011)	0.474*** (0.012)	0.239*** (0.030)	0.098*** (0.010)	0.013*** (0.002)	0.117*** (0.012)
Precipitation	-2.781*** (0.223)	-10.046*** (0.819)	-5.419*** (0.635)	-2.788*** (0.227)	-1.841*** (0.152)	-4.532*** (0.480)
Wind speed	-0.528*** (0.055)	0.090 (0.084)	-0.466*** (0.057)	-0.561*** (0.053)	-1.215*** (0.025)	-1.780*** (0.267)
Daily electricity price (log)	0.447 (1.009)	1.118 (1.020)	0.734 (1.023)	0.589 (1.006)	1.217*** (0.211)	1.818* (1.103)
Solar irradiance	76.349*** (22.231)	772.906*** (15.585)	307.611*** (45.808)	80.256*** (22.172)	62.418*** (5.055)	158.734*** (25.984)
Constant	4.185 (4.546)			4.170 (4.518)		
Fixed effect						
Building	Y	Y	Y	Y	Y	Y
Weekend	Y	Y	Y	Y	Y	Y
Holiday	Y	Y	Y	Y	Y	Y
Month-of-year	Y	Y	Y	Y	Y	Y
Year	Y	Y	Y	Y	Y	Y
N	105304	105304	105304	103226	103226	103226
R ²	0.385		0.232	0.389		0.296

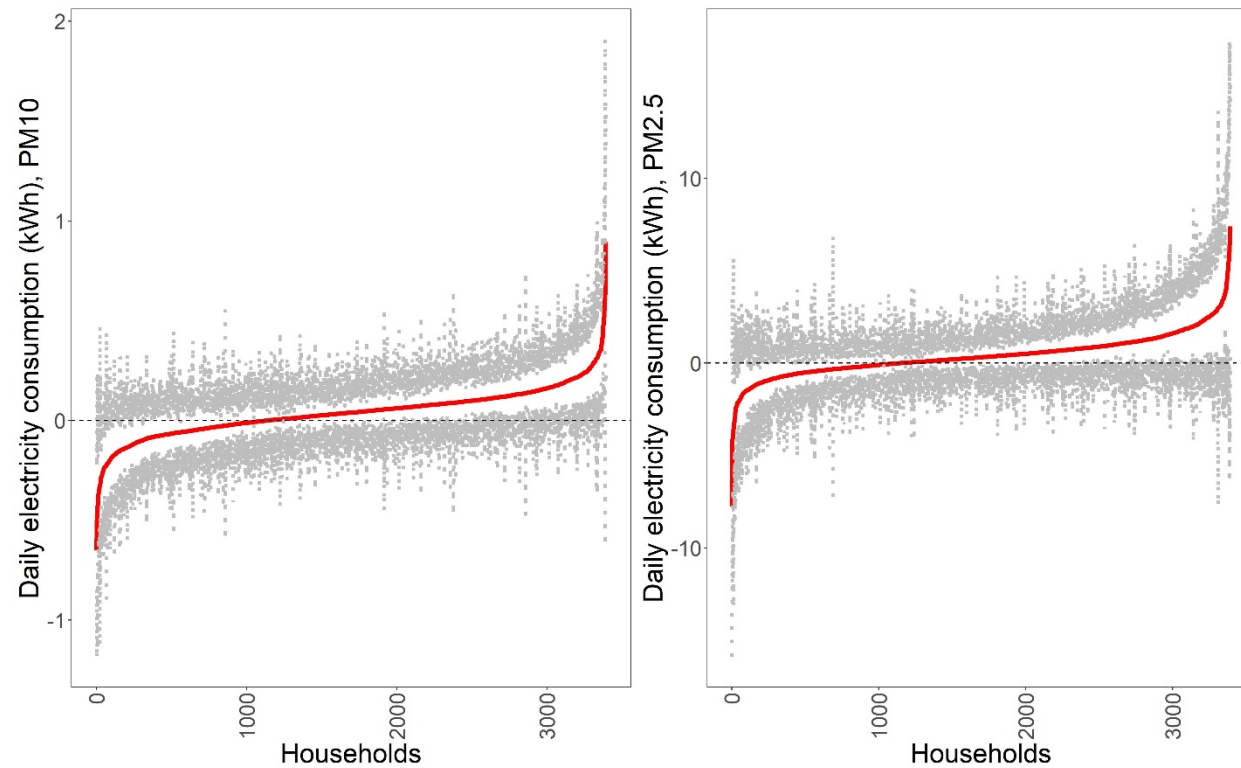
Notes: Standard errors in parentheses are clustered to building unit level. * p<0.1, ** p<0.05, *** p<0.01.

Supplementary Table 23 Effect of air pollution on solar energy generation in commercial buildings, IDW within 20km

	(1) GLS	(2) IV	(3) IV	(4) GLS	(5) IV	(6) IV
Wind cosine		5.828*** (0.028)			1.733*** (0.012)	
PM10 concentration	-0.013*** (0.002)		-0.026** (0.013)			
PM2.5 concentration				-0.041*** (0.008)		-0.106*** (0.037)
Heating degree days	-0.036*** (0.008)	-0.333*** (0.002)	-0.041*** (0.009)	-0.018** (0.007)	0.310*** (0.001)	0.002 (0.012)
Cooling degree days	0.032*** (0.005)	0.137*** (0.002)	0.034*** (0.006)	0.030*** (0.005)	-0.019*** (0.000)	0.029*** (0.005)
Precipitation	-0.457*** (0.091)	-14.850*** (0.156)	-0.643*** (0.223)	-0.363*** (0.089)	-2.673*** (0.030)	-0.528*** (0.151)
Wind speed	0.079*** (0.021)	-0.520*** (0.007)	0.073*** (0.019)	0.038*** (0.012)	-1.354*** (0.002)	-0.048 (0.045)
Demand charge (log)	2.336* (1.265)	-7.413*** (0.108)	2.238* (1.225)	2.507* (1.298)	0.187*** (0.026)	2.515* (1.300)
Energy charge (log)	-3.137*** (0.843)	-13.569*** (0.295)	-3.308*** (0.927)	-3.112*** (0.853)	-2.256*** (0.059)	-3.253*** (0.894)
Solar irradiance	53.757*** (8.326)	219.214*** (1.013)	57.020*** (8.478)	48.596*** (7.679)	-16.015*** (0.243)	48.150*** (7.664)
Constant	-18.432*** (4.839)			-17.738*** (4.872)		
Fixed effect						
Building	Y	Y	Y	Y	Y	Y
Weekend	Y	Y	Y	Y	Y	Y
Holiday	Y	Y	Y	Y	Y	Y

Month-of-year	Y	Y	Y	Y	Y	Y
Year	Y	Y	Y	Y	Y	Y
N	11804506	11804106	11804106	11485931	11485679	11485679
R ²	0.001		0.001	0.001		0.001

Notes: Standard errors in parentheses are clustered to building unit level. * p<0.1, ** p<0.05, *** p<0.01.



Supplementary Figure 1 The effect of air pollution on residential daily electricity consumption, individual coefficients. The red line shows the coefficient ranking from the smallest to the largest. The grey dotted lines show the 95% confidence intervals of the coefficients. We excluded the buildings with records fewer than 3 years which account for 920/3393=27% of the sample.