

Supplementary Materials: Energy Service Demand Projections and CO₂ Reduction Potentials in Rural Households in 31 Chinese Provinces

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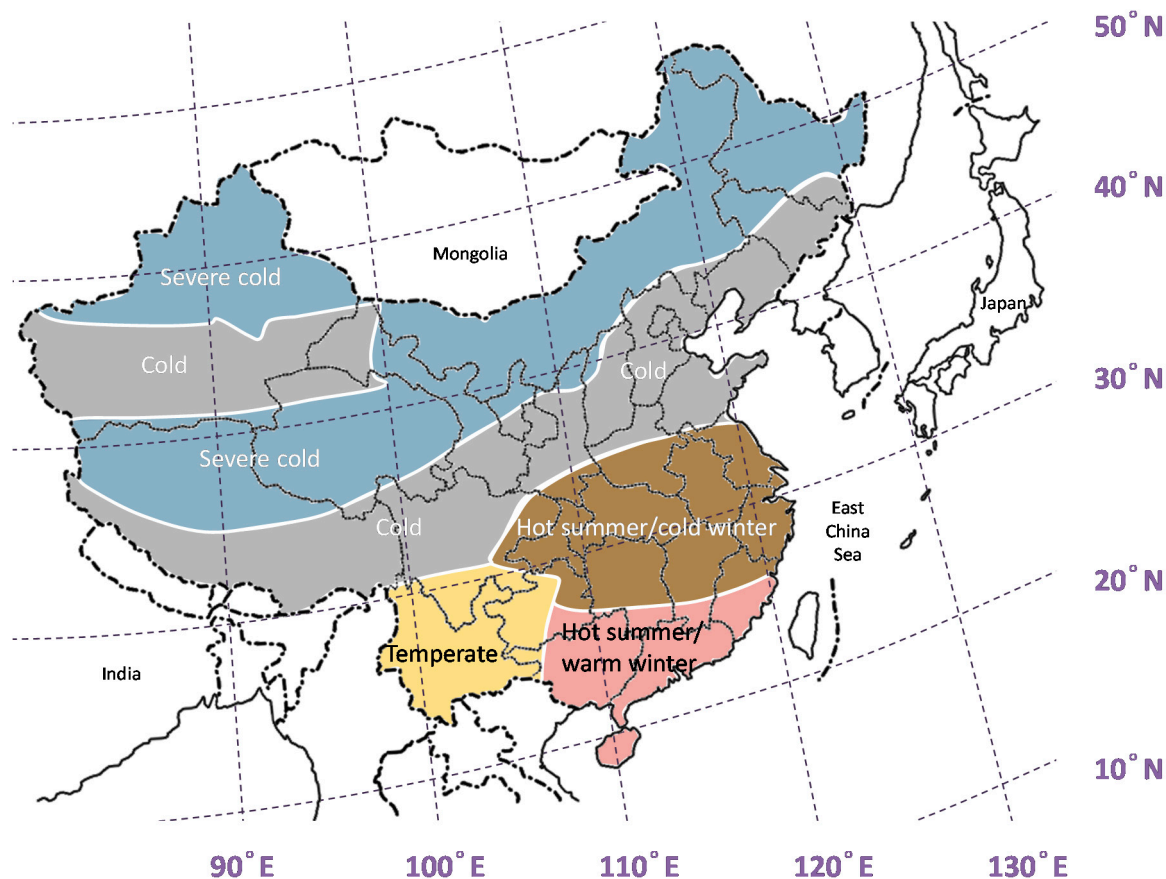


Figure S1. China's climate zones.

Table S1. Regional residential floor area (rural, million m²).

Province	2020	2030	2040	2050
Heilongjiang	303.86	267.55	220.83	176.49
Inner Mongolia	194.96	179.61	156.73	132.32
Qinghai	50.31	47.78	42.48	36.33
Tibet	40.74	42.16	41.78	39.88
Xinjiang	221.68	228.08	225.16	214.57
Jilin	235.75	214.82	184.30	152.91
Liaoning	343.08	306.49	265.70	223.64
Beijing	125.15	131.19	152.52	174.52
Tianjin	83.48	83.60	87.90	90.36
Hebei	890.84	829.20	739.83	636.48
Shandong	1184.40	1093.14	964.72	819.95
Ningxia	56.62	54.96	51.28	46.23
Sichuan	1105.28	926.87	745.62	578.05
Shaanxi	427.39	382.62	328.15	271.23
Shanxi	356.61	329.68	292.87	251.22
Gansu	225.51	200.53	170.99	140.51
Shanghai	185.65	182.31	210.72	241.67

Table S1. *Cont.*

Province	2020	2030	2040	2050
Anhui	704.34	607.38	500.84	397.46
Henan	1258.07	1118.35	950.28	776.97
Jiangsu	1152.75	1091.35	990.78	870.97
Chongqing	357.13	296.44	233.34	177.70
Hunan	1042.15	897.55	740.96	589.45
Zhejiang	1067.97	1066.86	1026.95	959.87
Hubei	865.16	749.11	609.09	478.14
Jiangxi	702.50	654.92	583.34	500.13
Yunnan	560.13	536.14	493.32	438.28
Guizhou	389.40	334.04	274.52	217.22
Guangxi	601.28	537.03	459.13	378.03
Guangdong	931.66	1018.12	1086.94	1129.57
Fujian	611.49	594.99	549.93	491.57
Hainan	73.74	69.92	63.84	56.36

Table S2. Ownerships of household electronics (unit/household).

Province	Appliance	2020	2030	2040	2050
Heilongjiang	Washing machine	0.847	0.908	0.953	0.989
	Refrigerator	0.564	0.647	0.708	0.757
	Television	1.112	1.119	1.125	1.129
	Computer	0.241	0.290	0.321	0.344
Inner-Mongolia	Washing machine	0.679	0.750	0.803	0.845
	Refrigerator	0.553	0.635	0.696	0.744
	Television	1.078	1.098	1.113	1.124
	Computer	0.130	0.159	0.178	0.193
Qinghai	Washing machine	0.802	0.906	0.983	1.045
	Refrigerator	0.538	0.622	0.685	0.734
	Television	1.114	1.170	1.212	1.245
	Computer	0.092	0.113	0.127	0.137
Tibet	Washing machine	0.143	0.169	0.187	0.201
	Refrigerator	0.206	0.238	0.262	0.281
	Television	0.827	0.972	1.074	1.153
	Computer	0.005	0.006	0.006	0.006
Xinjiang	Washing machine	0.561	0.618	0.660	0.693
	Refrigerator	0.499	0.566	0.615	0.654
	Television	1.051	1.072	1.088	1.101
	Computer	0.139	0.172	0.193	0.209
Jilin	Washing machine	0.840	0.896	0.937	0.970
	Refrigerator	0.517	0.593	0.649	0.694
	Television	1.144	1.157	1.168	1.176
	Computer	0.247	0.302	0.338	0.364
Liaoning	Washing machine	0.772	0.806	0.832	0.852
	Refrigerator	0.634	0.713	0.772	0.818
	Television	1.142	1.149	1.154	1.158
	Computer	0.248	0.300	0.334	0.358
Beijing	Washing machine	1.019	1.041	1.057	1.070
	Refrigerator	1.124	1.172	1.208	1.237
	Television	1.465	1.539	1.595	1.639
	Computer	0.772	0.851	0.902	0.939

Table S2. *Cont.*

Province	Appliance	2020	2030	2040	2050
Tianjin	Washing machine	1.042	1.075	1.100	1.119
	Refrigerator	0.968	1.048	1.107	1.154
	Television	1.349	1.426	1.482	1.527
	Computer	0.484	0.578	0.639	0.684
Hebei	Washing machine	0.940	1.001	1.046	1.082
	Refrigerator	0.602	0.669	0.718	0.758
	Television	1.242	1.255	1.264	1.272
	Computer	0.358	0.437	0.489	0.527
Shandong	Washing machine	0.803	0.905	0.980	1.040
	Refrigerator	0.664	0.745	0.806	0.854
	Television	1.169	1.186	1.199	1.208
	Computer	0.392	0.475	0.529	0.568
Ningxia	Washing machine	0.802	0.876	0.931	0.975
	Refrigerator	0.382	0.436	0.475	0.507
	Television	1.313	1.359	1.393	1.420
	Computer	0.188	0.230	0.258	0.278
Sichuan	Washing machine	0.683	0.765	0.826	0.875
	Refrigerator	0.498	0.573	0.629	0.673
	Television	1.173	1.204	1.228	1.246
	Computer	0.119	0.143	0.158	0.170
Shaanxi	Washing machine	0.763	0.866	0.937	0.992
	Refrigerator	0.320	0.367	0.401	0.428
	Television	1.288	1.357	1.407	1.448
	Computer	0.225	0.275	0.307	0.331
Shanxi	Washing machine	0.902	0.978	1.035	1.081
	Refrigerator	0.381	0.425	0.457	0.483
	Television	1.178	1.204	1.223	1.239
	Computer	0.326	0.397	0.443	0.477
Gansu	Washing machine	0.702	0.781	0.839	0.885
	Refrigerator	0.211	0.241	0.264	0.282
	Television	1.180	1.233	1.273	1.304
	Computer	0.134	0.163	0.182	0.196
Shanghai	Washing machine	0.958	0.999	1.030	1.054
	Refrigerator	1.052	1.103	1.140	1.169
	Television	2.106	2.199	2.268	2.323
	Computer	0.583	0.610	0.628	0.641
Anhui	Washing machine	0.582	0.656	0.712	0.756
	Refrigerator	0.627	0.717	0.784	0.837
	Television	1.259	1.282	1.299	1.312
	Computer	0.166	0.200	0.222	0.238
Henan	Washing machine	0.911	1.019	1.099	1.163
	Refrigerator	0.463	0.529	0.577	0.616
	Television	1.159	1.186	1.206	1.222
	Computer	0.236	0.288	0.321	0.346
Jiangsu	Washing machine	0.946	1.023	1.079	1.125
	Refrigerator	0.717	0.801	0.862	0.911
	Television	1.522	1.575	1.614	1.646
	Computer	0.437	0.517	0.569	0.607

Table S2. *Cont.*

Province	Appliance	2020	2030	2040	2050
Chongqing	Washing machine	0.533	0.607	0.663	0.707
	Refrigerator	0.568	0.653	0.716	0.766
	Television	1.123	1.156	1.180	1.199
	Computer	0.166	0.204	0.228	0.246
Hunan	Washing machine	0.465	0.541	0.595	0.636
	Refrigerator	0.496	0.569	0.623	0.666
	Television	1.187	1.230	1.262	1.287
	Computer	0.145	0.176	0.196	0.212
Zhejiang	Washing machine	0.737	0.807	0.858	0.899
	Refrigerator	0.981	1.075	1.145	1.201
	Television	1.810	1.895	1.957	2.006
	Computer	0.583	0.666	0.720	0.760
Hubei	Washing machine	0.506	0.562	0.603	0.636
	Refrigerator	0.549	0.629	0.689	0.737
	Television	1.201	1.231	1.254	1.272
	Computer	0.232	0.282	0.314	0.338
Jiangxi	Washing machine	0.175	0.199	0.217	0.231
	Refrigerator	0.467	0.538	0.590	0.632
	Television	1.267	1.305	1.332	1.355
	Computer	0.156	0.190	0.212	0.228
Yunnan	Washing machine	0.464	0.515	0.552	0.582
	Refrigerator	0.205	0.235	0.257	0.275
	Television	1.039	1.090	1.128	1.158
	Computer	0.068	0.083	0.092	0.099
Guizhou	Washing machine	0.579	0.655	0.710	0.755
	Refrigerator	0.291	0.336	0.369	0.396
	Television	0.987	1.048	1.093	1.129
	Computer	0.054	0.064	0.071	0.076
Guangxi	Washing machine	0.200	0.228	0.249	0.265
	Refrigerator	0.354	0.409	0.450	0.483
	Television	1.213	1.268	1.308	1.340
	Computer	0.141	0.172	0.192	0.207
Guangdong	Washing machine	0.478	0.519	0.549	0.572
	Refrigerator	0.520	0.583	0.630	0.667
	Television	1.226	1.260	1.286	1.306
	Computer	0.371	0.428	0.466	0.493
Fujian	Washing machine	0.690	0.749	0.793	0.828
	Refrigerator	0.788	0.888	0.962	1.020
	Television	1.353	1.394	1.423	1.447
	Computer	0.435	0.509	0.557	0.593
Hainan	Washing machine	0.116	0.129	0.139	0.147
	Refrigerator	0.207	0.236	0.257	0.274
	Television	1.098	1.186	1.252	1.304
	Computer	0.099	0.119	0.133	0.143

Table S3. List of technologies considered in the AIM/Enduse model.

Appliance	Energy Source	Efficiency (Provided/Consumed)	Technology Number
Heating			
Coal stove	Coal	Existing (EXT, 0.39), best available (BAT, 0.8)	2
Commercial biomass stove	Commercial biomass	EXT (0.8), BAT (0.88)	2
Non-commercial biomass stove	Firewood, straw	EXT (0.39)	2
Hot water			
Coal stove water heater	Coal	EXT (0.53)	1
Non-commercial biomass stove water heater	Firewood, straw	EXT (0.53)	2
LPG water heater	Liquefied petroleum gas (LPG)	EXT (0.8), BAT (0.87)	2
Solar water heater	Solar thermal	EXT (1.0)	1
Commercial biomass stove water heater	Commercial biomass	NEW (0.8)	1
Cooking			
Modern cooking range	LPG, grid electricity, diesel electricity	EXT (LPG 0.53; GE 0.53; DE 0.19), BAT (LPG 0.56; GE 0.56; DE 0.20)	6
Traditional cooking range	Coal, firewood, straw	EXT (0.53)	3
Commercial biomass cooking range	Commercial biomass	NEW (0.53)	1
Lighting			
Incandescent lamp	Grid electricity, diesel electricity, photovoltaics, wind turbine	EXT (1.05), NEW (4.95)	8
Fluorescent lamp	Grid electricity, diesel electricity, photovoltaics, wind turbine	EXT (4.95), NEW (5.26), BAT (6.32)	12
LED	Grid electricity, diesel electricity, photovoltaics, wind turbine	EXT (5.26)	4
Electronics			
Refrigerator	Grid electricity, diesel electricity, photovoltaics, wind turbine	EXT (0.63), NEW (1.0), BAT (1.43)	12
Television	Grid electricity, diesel electricity, photovoltaics, wind turbine	EXT (1.0), NEW (1.11), BAT (1.43)	12
Other equipment	Grid electricity, diesel electricity, photovoltaics, wind turbine	EXT (0.77), NEW (1.0), BAT (1.0)	12

Table S4. Building energy demand (China, 450 Scenario) [15]. Unit: Mtoe.

Energy	2020	2030	2040
Buildings	512	516	512
Coal	62	45	29
Oil	32	17	8
Gas	55	77	85
Electricity	145	172	191
Heat	25	24	23
Bioenergy	167	139	124
Other renewables	27	42	51

File S1. Disaggregation of socioeconomic indicators [38]

The compound population growth rate of each province is estimated by using Equation (1).

$$X_{t,r \in (X_{t0,r} > X_{t0,ave})} = X_{t,ave} + (X_{t,max} - X_{t,ave}) \frac{X_{t0,r} - X_{t0,ave}}{X_{t0,max} - X_{t0,ave}} \quad (1)$$

$$X_{t,r \in (X_{t0,r} \leq X_{t0,ave})} = X_{t,ave} - (X_{t,ave} - X_{t,min}) \frac{X_{t0,ave} - X_{t0,r}}{X_{t0,ave} - X_{t0,min}}$$

where

r	Is region or province
t	Is year
$X_{t,r}$	Is the compound population growth rate in year t and province r
$X_{t,ave}$	Is the national average of population growth rate in year t from SSPs
$X_{t,max}$	Is the assumed maximum value of population growth rate in year t
$X_{t,min}$	Is the assumed minimum value of population growth rate in year t
t_0	Is the benchmark year (2010)

Based on the growth rate, the annual provincial population is estimated by using Equation (2). Additionally, to keep the total population consistent with SSP2's projection, we use Equation (3) to adjust the provincial population.

$$POP_{t,r} = POP_{t-1,r} \times X_{t,r} \quad (2)$$

where

$POP_{t,r}$	Is the provincial population in year t and province r
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$$POP_{t,r} = POP_0 \times \frac{POP_{t,r}}{\sum_r POP_{t,r}} \quad (3)$$

where

$POP_{t,r}$	Is the adjusted regional population in year t and province r
POP_0	Is the national population in year t based on SSPs

File S2. Regression analysis of per capita floor area.

The per capita floor area in rural areas is estimated by using Equation (4). Coefficients of 31 provinces are listed in Table S5.

$$PCFA_t = a \times \ln(X_t) + b \quad (4)$$

where

$PCFA_t$	Is rural per capita floor area in year t
X_t	Is sequence of year t ($X_{2000} = 1$)
a, b	Are regression coefficients

Table S5. Coefficients of per capita floor area.

Province	a	b	r^2
Heilongjiang	2.4365	16.985	0.7961
Inner Mongolia	3.0896	14.984	0.8221
Qinghai	4.2136	12.348	0.5758
Tibet	4.2152	15.232	0.7443
Xinjiang	3.7191	15.141	0.8125
Jilin	2.9634	15.680	0.8285
Liaoning	2.7742	20.575	0.8442
Beijing	4.5346	27.994	0.8577
Tianjin	3.8011	19.802	0.9062
Hebei	4.7974	20.529	0.8766
Shandong	5.7550	20.474	0.8571
Ningxia	3.0974	16.619	0.8882
Sichuan	4.6585	25.105	0.8267
Shaanxi	4.6683	20.281	0.7027
Shanxi	3.4566	19.459	0.7793
Gansu	2.9706	14.122	0.7711
Shanghai	2.7834	53.900	0.699
Anhui	5.0712	19.331	0.8205
Henan	5.6316	19.754	0.7807
Jiangsu	6.8359	29.171	0.7978
Chongqing	3.9781	27.442	0.7611
Hunan	5.9422	28.513	0.8837
Zhejiang	7.1444	43.359	0.9049
Hubei	5.8479	26.710	0.8285
Jiangxi	7.2890	23.047	0.7796
Yunnan	3.6605	19.861	0.7822
Guizhou	3.8107	17.590	0.8108
Guangxi	5.1774	20.548	0.8720
Guangdong	3.4116	20.845	0.8584
Fujian	7.7502	28.381	0.8920
Hainan	2.5743	17.409	0.7642

Table S6. Electricity emission factor in Enduse/Global [1]. Unit: tCO₂/ktoe.

2010	2020	2030	2040	2050
11221.1183	11024.3672	11024.3672	11024.3672	11024.3672