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Does urbanization increase residential energy use? Evidence from the Chinese residential energy consumption survey 2012

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ABSTRACT

China's rapid urbanization and increasing energy use are accompanied by deteriorating environmental quality. Understanding the structure of energy use is necessary to address these environmental effects. We investigate how urbanization affects residential energy use, using data from the Chinese Residential Energy Consumption Survey 2012 (CRECS 2012). By comparing the energy consumption of urban and rural households and identifying the factors influencing the differences, we find that dwelling characteristics (e.g., building infrastructure, residential area), household characteristics (e.g., household size, income), and unobservable factors (e.g., the surrounding environment, living habits) all play roles in shaping residential energy consumption. Urbanization directly decreases energy consumption through differences in the environment outside the household (markets, infrastructure, etc.), while it indirectly increases consumption through the presence of central heating, decreased household size, and increased household income. We find a positive total effect: urbanization increases residential energy consumption in total. We also find that urbanization shifts energy consumption away from coal and toward electricity and gas. In addition, we distinguish between onsite urbanization (formation of towns based on rural markets) and offsite urbanization (movement to large cities). Compared to onsite urbanization, offsite urbanization shifts energy consumption toward electricity and gas by a larger magnitude. Finally, we project residential energy use in 2020.

1. Introduction

China's rapid growth and urbanization have been accompanied by a rapid increase in energy consumption and emission of pollutants (Sun, Ouyang, Cai, Luo, & Li, 2014). In the last 35 years, more than 500 million rural residents in China migrated to urban areas. By 2030, China is expected to have over one billion urban residents (Normile, 2008) and the urban areas are expected to account for 83% of the total energy consumption in China if urbanization continues along the current path (IEA, 2007). The proportion of the population living in urban areas in China increased from 36.2% to 56.1% from 2000 to 2015, while urbanization rates in other major countries, such as the U.S. and India, are stable, as shown in Fig. 1, Panel A. A particular feature of China's urbanization is the growth of towns in rural areas, in addition to migration from rural areas to existing cities. Because China's early 21st century urbanization has differed from most other major economies in both its rate and its structure, it is important to study the effects of urbanization on energy consumption in the specific context of China.

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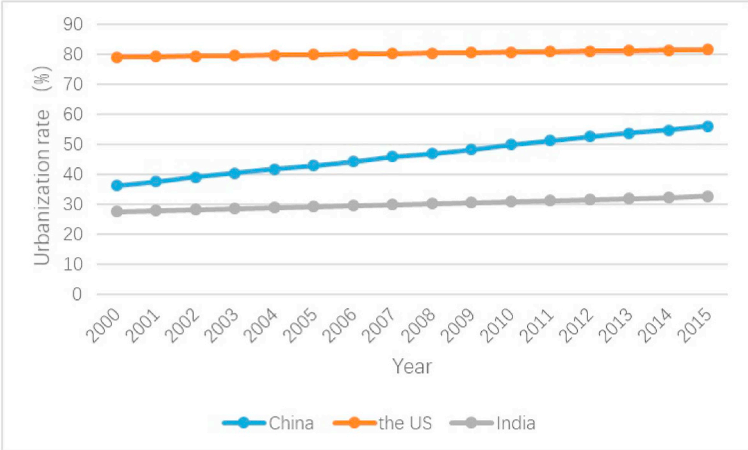
Panel A: Urbanization rate in China, the US, and India



Panel B: Urbanization rate and energy consumption in China

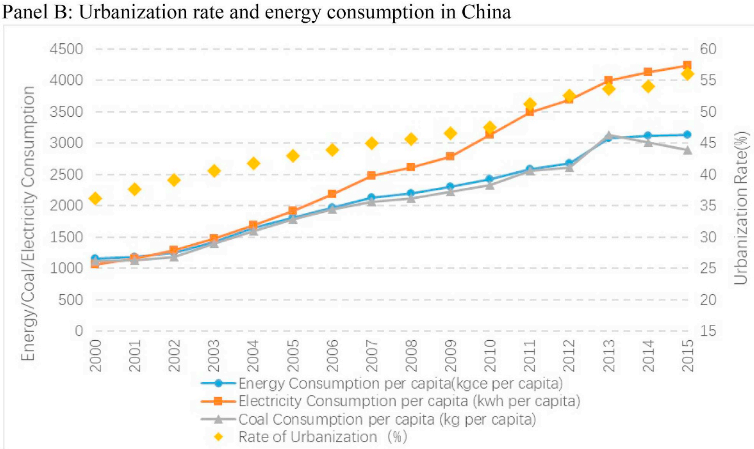


Fig. 1. Urbanization and Energy Consumption in China since 2000.
Panel A: Urbanization rate in China, the US, and India.
Panel B: Urbanization rate and energy consumption in China.
Notes: Data are from State Statistical Bureau from 2000 through 2015.

Per capita energy consumption in China has been increasing alongside the increase in urban population. The structure of energy consumption has shifted toward electricity and away from coal,[1] as shown in Fig. 1, Panel B. Even with this shift, energy use results in environmental problems such as emission of local pollutants and greenhouse gases. Therefore, the Chinese government has carried out a series of policies to reduce energy consumption (e.g. Du, Lin, Sun, & Zhang, 2015; Li & Sun, 2018), and put forward an "intensive, intelligent, green, low-carbon" plan for urbanization.[2] To achieve this goal, it is critical to understand the mechanism through which urbanization affects energy use. Therefore, this paper investigates the factors that influence the differences in energy consumption between urban and rural households, and looks into the direct and indirect effects of urbanization on energy consumption.

This paper is rooted in two series of studies. One series of studies takes the angle of "top down". These papers start from the characteristics of urbanization, systematically state the impacts of urbanization on energy and environment, and investigate the mechanism of the impacts. The analytical tools include the theories of ecological modernization (e.g., Fudge & Rowe, 2001; Mol, 2006; Zhang, Mol, & Sonnenfeld, 2007), urban environmental evolution (e.g., Bai & Imura, 2000; Marcotullio, 2003; McGranahan & Satterthwaite, 2002), and compact cities (e.g., Burton, 2000; Capello & Camagni, 2000). Regarding whether urbanization increases energy consumption, empirical studies have mixed findings. Some studies find that urbanization leads to an increase in urban energy demand through changing related production, transportation, infrastructure, and other aspects of the living environment (e.g., Creutzig, Baiocchi, Bierkandt, Pichler, & Seto, 2015; Holtedahl & Joutz, 2004; Jones, 1991; Madlener & Sunak, 2011; Parikh &

[1] Coal is primary energy and electricity is secondary energy. In China, about 60% of electricity is generated from coal. To avoid double counting, coal for electricity generation is not counted when electricity is counted in energy consumption.
[2] Source: 2012 Central Economic Work Conference. http://english.cntv.cn/special/2012economicmeeting/homepage/index.shtml

Shukla, 1995; Poumanyvong, Kaneko, & Dhakal, 2012; York, 2007). In contrast, some other studies find that urbanization does not necessarily increase energy consumption due to the economies of scale and improvement of energy efficiency resulting from the transition to modern energy (e.g., Mishra, Smyth, & Sharma, 2009; Pachauri, 2004; Pachauri & Jiang, 2008).

The other strand of literature takes the angle of "bottom up". These studies start from micro-level decision makers – households or individuals – and analyze the mechanism through which urbanization affects households' energy use behavior. Depending on the mechanism, this series of literature can be divided into three categories. One category focuses on household characteristics. Researchers find that urbanization increases household income through providing more job opportunities and better public services such as education. They also find that households in cities tend to have younger household heads, smaller household sizes, and a smaller residential area. All these differences in the characteristics of the household affect their living habits and energy consumption behavior (Ironmonger, Aitken, & Erbas, 1995; Sardianou, 2007; Song & Xiao, 2006). The second category focuses on the difference in the external environment in which individuals make decisions, such as markets, infrastructure, policies, etc. Urbanization provides better roads, communication and financial infrastructure, which lead to better access to markets and information. All of these changes in the environment affect residents' energy consumption behavior as well (Jiang & Zhi, 2011; Wang, 2010; Xia & Chen, 2004). The last category focuses on the direct impact of urbanization. Urbanization changes related infrastructural facilities and equipment, such as dwelling characteristics, energy-using appliances, etc. For instance, urbanization changes residents' energy choice set and increases the heat retention of homes, which directly changes residents' energy consumption (Dodman, 2009; Jiang & Zhi, 2011).

This paper fits into the second series of the literature. Taking a "bottom-up" angle requires household or individual level data. Due to the lack of comprehensive data at the fine level, previous studies in China mainly focus on regional difference in energy use or are limited to one type of energy or one category of factors that influence energy consumption (e.g., Tonooka, Liu, Kondou, Ning, & Fukasawa, 2006; Wang & Feng, 2003; Zhou & Teng, 2013). Utilizing data from the Chinese Residential Energy Consumption Survey 2012, this paper investigates energy consumption differences between urban and rural households nationwide, including not only the difference in quantity, but also the difference in structure of energy consumption. Findings based on nationwide surveys could be more generalizable compared to regional studies. This paper also identifies the factors that influence the energy consumption of households, including the characteristics of households and dwellings, as well as the unobservable difference between urban and rural areas, such as the external environment. Including these observed and unobserved factors could alleviate the omitted variable problem and increase the predictive power of the model. Finally, this paper simulates spatial residential energy consumption trends under urbanization scenarios, which could provide reference for policy makers.

Moreover, the paper contributes to the literature by distinguishing among different types of urbanization. Urbanization in China includes both offsite and onsite urbanization (Men & Qi, 2017). Offsite urbanization refers to rural residents' migration to large cities. Onsite urbanization, which is unique to China, refers to the formation of small towns based on rural markets and driven by the industrialization of rural areas (Zhao, 2003).[3] In China, offsite urbanization usually dominates in less developed rural areas, while onsite urbanization dominates in more developed rural areas (Lu, 2015). Both offsite and onsite urbanization are expected to increase energy consumption in urban areas and decrease energy consumption in rural areas, due to the population change in these areas. However, the nationwide total effect is ambiguous, because urbanization could increase energy demand through increasing income and better access to energy, while it could also decrease energy demand through economies of scale or better energy efficiency. This paper distinguishes between onsite and offsite urbanization, because the two forms of urbanization could have different effects on energy consumption, due to the differences between cities (offsite urbanization) and towns (onsite urbanization).

Based on the regression results, we find that household income, household size, education, and unobservable factors (e.g., market environment) all have significant influences on residential energy consumption. We quantify their respective contributions to energy consumption change and find that urbanization increases per capita energy consumption by 118 kg coal equivalent (kgce), increases electricity and gas by 21 kgce and 85 kgce, and decreases coal by 58 kgce. Interestingly, we find that offsite urbanization increases energy consumption by 167 kgce while onsite urbanization decreases energy usage by 15 kgce. Furthermore, we explore the possible reasons behind the findings.

The remainder of this paper is organized as follows. Section 2 describes the survey data and compares energy consumption between urban and rural households. Section 3 describes the empirical estimation strategy and presents the regression results. Section 4 simulates residential energy consumption change under urbanization scenarios. Section 5 repeats the empirical analysis with offsite and onsite urbanization distinguished. Section 6 concludes.

2. Data

The data used in this paper are from the Chinese Residential Energy Consumption Survey 2012, conducted by the Department of Energy Economics at Renmin University of China. The sample covers 95 prefecture-level or above cities, including 91 prefecture-level cities from 23 provinces in mainland China (omitting Jiangsu, Tibet, Qinghai and Shaanxi) and 4 municipalities directly under the Central Government, giving a sample of 1425 households in total. The number of sampled counties was determined based on population density, non-agricultural population share, and per capita gross regional product. The spatial distribution of the sampled

[3] In China, the administrative levels of cities are diverse. They are (from upper to lower) municipalities directly under the Central Government (*Zhixiashi*), prefecture-level cities (*Dijishi*) and county-level cities (*Xianjishi*). In this paper, city refers to the urban area of a county-level city or above. Town (*Zhen*) refers to the urbanized area out of municipal districts of a city, and usually surrounded by rural areas. Generally, the administrative level of a town is lower than a county-level city.

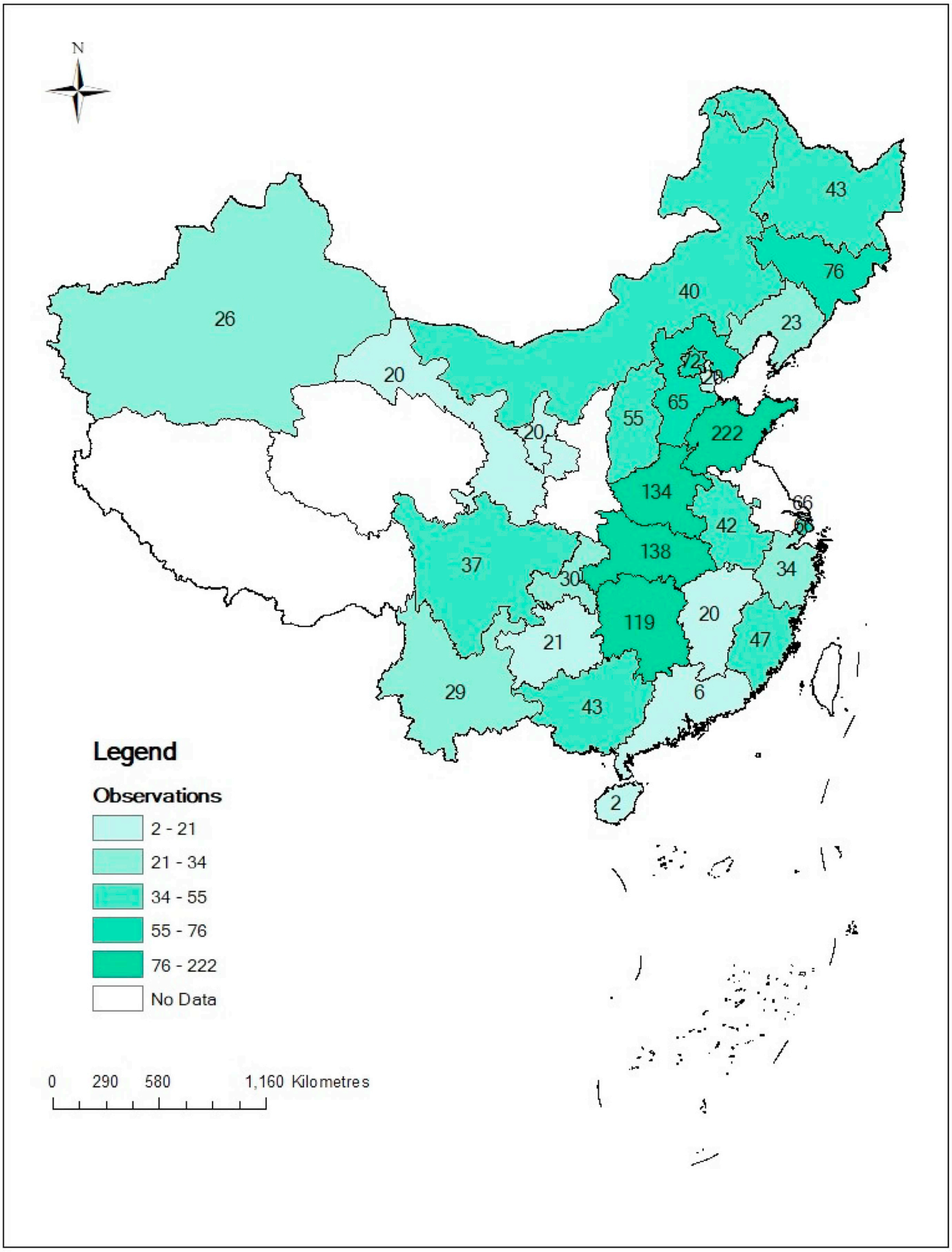


Fig. 2. Spatial Distribution of Sampled Households in CRECS 2012.

households is depicted in Fig. 2. It includes 905 households living in cities, 235 in towns, 4 living in urban areas but did not specify city or town, and 281 in rural areas.[4]

The survey collects information on (1) energy-using appliances owned by a sampled household (e.g., the power and energy efficiency of electric appliances); (2) the energy consumption habits of a household, including frequency and duration of all energy consumption activities (e.g. cooking, heating, cooling, heating water, and others) with the corresponding energy-using appliances;

[4] More information on the survey, including survey quality control and sampling criteria, can be found in Zheng et al. (2014).

(3) amounts of each type of energy consumed, including electricity, central heating,[5] coal, liquefied petroleum gas (LPG), natural gas, biomass energy (including firewood, agricultural residual, and manure), and solar energy; (4) household characteristics, including household income, each household member's education, employment, age, etc., and (5) characteristics of the residence, including size, age, whether it has central heating, etc.

To avoid recall error in energy consumption, we utilize the detailed information on energy consumption activities to calculate the amount of each energy type consumed, and then add up all types of energy to get the total amount of energy consumption. The calculation formula is as follows:

$$Energy_i = \sum_{m=1}^{M} \sum_{n=1}^{N} (Energy_{i,m,n} \times coef_n) \tag{1}$$

where $Energy_i$ is the total amount of energy consumed by household i in the survey year, measured in kilogram coal equivalent (kgce); $Energy_{i,\ m,\ n}$ is the amount of energy type n consumed by household i in activity m, measured in energy type n's usual unit (e.g., electricity is measured in kwh, natural gas is measured in cubic meters, etc.); and $coef_n$ is the conversion coefficient, which transforms physical quantity of energy type n into a standard quantity in kgce. The conversion coefficients are collected from the China Energy Statistical Yearbook.

The conversion coefficient and the amount of per capita consumption of each energy type, in both physical quantity and standard quantity (kcge) are summarized in Table A1 in the appendix. It shows that the most used energy types in China are central heating, natural gas, electricity, biomass, and LPG. Coal is not among the most used energy types since urban areas in China no longer widely use coal for household activities.

We compare residential energy consumption between urban and rural households. Fig. 3 illustrates the distribution of per capita energy consumption in urban and rural areas. It shows that per capita energy consumption is distributed log-normally in both areas, and that the distribution of urban areas is to the right of the distribution of rural areas, indicating more energy consumption in urban areas. We further distinguish between extensive and intensive margins of energy consumption. Extensive margin refers to whether a household uses a certain type of energy, measured as penetration rate. Intensive margin refers to the amount of energy consumed, conditional on the use of that energy type. Panel A of Table 1 summarizes the penetration rates of energy types in urban and rural areas. It shows that all urban and rural households in the sample have access to electricity. This is expected, because access to electricity in China reached 99.8% in 2012.[6] Penetration rates of central heating and natural gas are higher in urban areas, where infrastructure is better developed. Compared to urban households, a larger portion of rural households use coal, LPG, and biomass energy. Panels B and C of Table 1 compare the total energy consumption and the consumption of each type of energy in urban and rural areas. This shows that, besides electricity, the main energy types in urban areas are central heating and natural gas, while the main energy types in rural areas are biomass energy, LPG and coal.

As we discussed in the previous section, there are many factors that affect residential energy consumption, such as dwelling characteristics, household characteristics, and the external environment in which households undertake energy consumption activities. We summarize in Table 2 the factors that are observed. We compare these factors between rural and urban areas. Given that urbanization in China includes the two forms of offsite and onsite urbanization, we divide urban areas into cities and towns, corresponding to offsite and onsite urbanization respectively. Table 2 shows that, compared to rural households, urban households on average have newer and smaller dwelling spaces, higher income, smaller household size, and higher levels of education. It also shows that, compared to town households, city households have newer and smaller residential spaces and higher income and education, and are more likely to have central heating. These differences confirm the importance of distinguishing onsite and offsite urbanization when simulating the effect of urbanization on energy consumption.

3. Empirical analysis

In this section, we investigate the correlation between energy consumption and the influencing factors, including household and dwelling characteristics and unobserved differences between urban and rural areas. The unobserved differences could include energy price, access to energy, energy-saving consciousness, and consumers' willingness to pay for convenience, safety and cleanness, etc. We use a dummy variable of *urban* to capture these unobserved differences between urban and rural areas. We also include location dummies (province and county) to capture the effects of additional unobserved differences in areas, such as differences in weather and energy price across provinces or counties.

The regression equation is as follows:

$$ln(Y_i) = \beta_0 + \beta_1 D_i + \boldsymbol{X_i}'\boldsymbol{\beta_2} + \boldsymbol{Z_i}'\boldsymbol{\beta_3} + \varepsilon_i \tag{2}$$

where Y_i is the per capita energy consumption of household i; D_i is a dummy variable which equals one if household i lives in an urban area and zero otherwise; $\boldsymbol{X_i}$ is a vector of characteristics of the dwelling in which household i lives; $\boldsymbol{Z_i}$ is a vector of characteristics of household i; and ε_i is the error term.

[5] Central heating refers to the type of energy provided by a district central heating system. For example, in Northern China, it is common for a community (hundreds or thousands of households) to be served by a central heating system. The system generates and transports heated water or steam from coal or gas boilers into households. Since no meter is installed in the households, households do not know the quantity of central heating they consume. We therefore calculate the quantity based on Eq. (1).

[6] http://www.nea.gov.cn/2015-12/24/c_134948340.htm

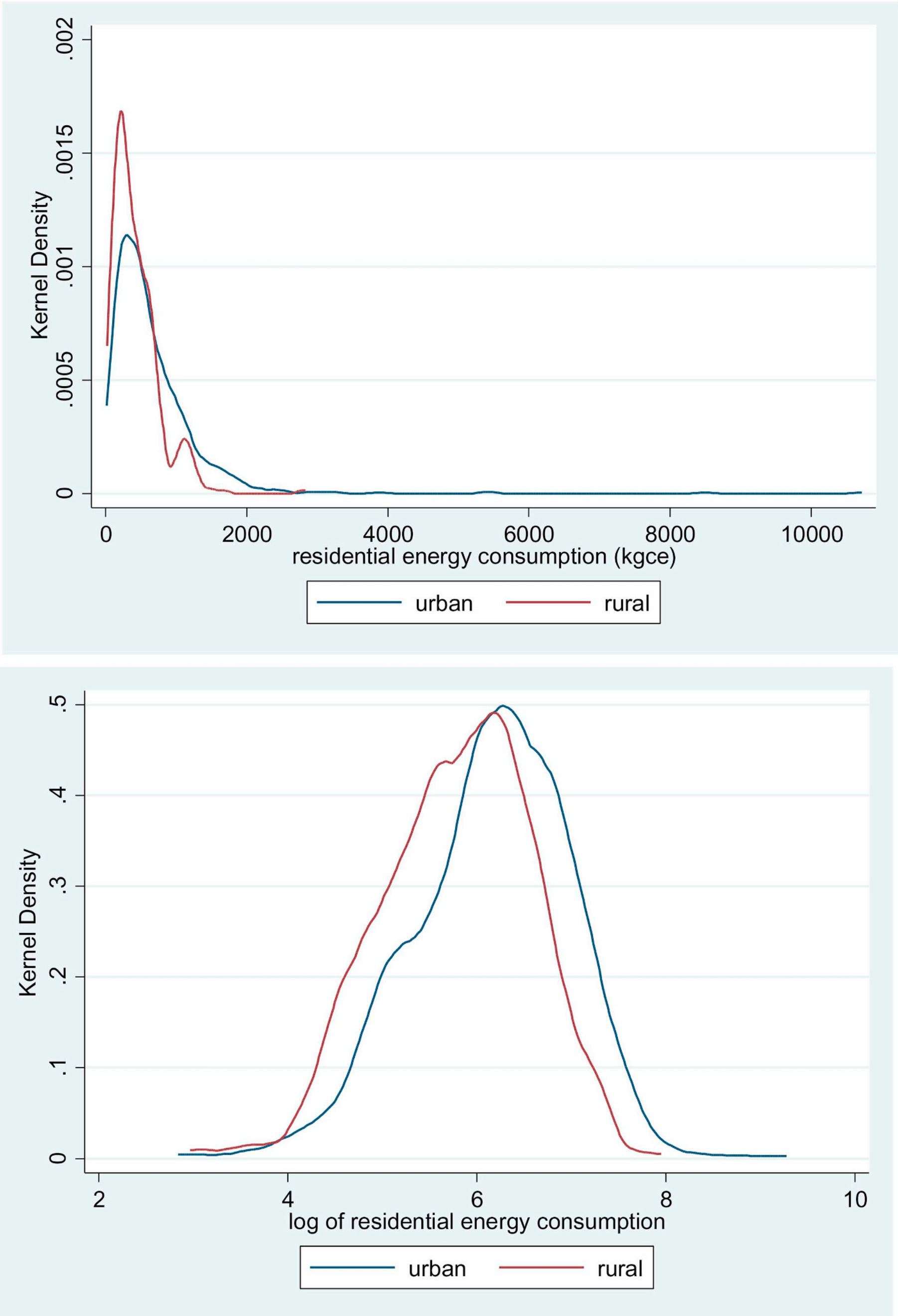


Fig. 3. Distribution of Residential Energy Consumption in Urban and Rural Areas.
Notes: Total energy consumption per capita and the natural logarithm of the total energy consumption per capita are depicted, respectively.

We employ fixed effect models to estimate Eq. (2) and present regression results in Table 3. The first three columns of Table 3 use a province fixed effects model and the last column uses a county fixed effects model. Column (1) includes only the dummy variable *urban*. The estimated coefficient of *urban* is 0.177 and is statistically significant at the 1% significance level. It shows that the energy consumption of urban households on average is 17.7% higher than rural households in the same province. Column (2) adds in dwelling characteristics. Column (3) further adds in household characteristics. Column (4) has the same specification as Column (3), but replaces province fixed effects with county fixed effects. The estimated coefficient of *urban* becomes negative as household and dwelling characteristics are added. This indicates that urban households consume less energy, compared to households with the same characteristics that live in rural areas in the same county.

We use Column (4) in Table 3 as the main result. It controls for all the observed characteristics and adopts a finer level of fixed

Table 1
Summary statistics of energy consumption.

Panel A: Penetration rates of energy types in urban and rural areas.

	Urban	Rural	Difference
Electricity	100.00%	100.00%	0.00%
Central heating	49.00%	1.77%	47.23%***
Coal	4.71%	43.10%	−38.39%***
LPG	25.50%	58.00%	−32.50%***
Natural gas	64.00%	7.07%	56.93%***
Biomass energy	8.48%	78.10%	−69.62%***
Solar energy	18.10%	33.60%	−15.50%**
No. of obs.	1144	281	–

Panel B: Energy consumption per capita in urban and rural areas (Full sample).

	Urban	Rural	Difference
Total	650.1	428.1	222.01***
Electricity	102.1	65.70	36.39***
Central heating	358.0	9.173	348.86***
Coal	1.798	25.61	- 23.81***
LPG	36.97	45.20	−8.24***
Natural gas	128.2	11.71	116.52***
Biomass energy	23.00	270.7	- 247.68***
Solar energy	0.0398	0.0672	−0.027
No. of obs.	1144	281	

Panel C: Energy consumption per capita in urban and rural areas (Non-zero Sample).

	Urban		Rural		Difference
	Mean	Obs.	Mean	Obs.	
Total	650.15	1144	428.14	281	222.01***
Electricity	102.09	1144	65.70	281	36.39***
Central heating	724.94	565	515.52	5	209.42***
Coal	38.80	53	59.97	120	- 21.16***
LPG	143.84	294	78.40	162	65.43***
Natural gas	201.21	729	164.46	20	36.75***
Biomass energy	265.78	99	347.32	219	- 81.54***
Solar energy	0.201	206	0.220	94	0.02

Notes: The first two columns in Panel A summarize the penetration rates of energy types in urban and rural areas, respectively. The last column shows the differences. Panels B and C show the standard quantity of residential energy consumption per capita in urban and rural areas for both full and non-zero samples. The significance level is indicated by stars: *** indicates 1% significance level, ** 5%, and * 10%, respectively.

effects so that it captures more detailed unobservable characteristics of each county. It shows that urban households consume 26.4% percent less energy than otherwise identical rural households. This finding suggests that urbanization improves energy efficiency, which is in line with former literature (e.g., Mishra et al., 2009; Pachauri, 2004; Pachauri & Jiang, 2008). In addition, the other estimated coefficients show that, as expected, older houses, larger living areas, and houses with central heating consume more energy. The coefficient of household size is negative and statistically significant, indicating the existence of economies of scale. The coefficient of household average age is positive, indicating that younger households use less energy than older households. The possible reason could be that young households engage less in energy-consuming activities (e.g., cooking) or are more likely to use appliances of better energy efficiency.

In addition to total quantity of energy consumption, the structure of energy consumption is also important. Therefore, we also investigate how the consumption of main energy types changes along with urbanization. For each of the main energy types, including electricity, gas (natural gas and LPG together), and coal, we distinguish between extensive and intensive margins.

To investigate the extensive margin, we generate a dummy variable, which equals one if the main energy is consumed, and then regress the dummy variable on all the dwelling and household characteristics, the urban dummy, and the county fixed effects, the same specification as Column (4) in Table 3. For the extensive margins of gas and coal, we use both a Probability Linear Model (PLM) and a Logit model. We do not investigate the extensive margin of electricity, because all the households in the survey have access to electricity, as shown in Table 1.

The estimated marginal effects are reported in Table 4. It shows that urbanization improves gas accessibility and reduces the portion of households that use coal; older households are less likely to use gas and more likely to use coal; houses with a central heating system are less likely to use coal and more likely to use gas. The possible reason could be that houses with central heating are those with better infrastructure, such as gas pipelines. The effect of annual income per capita on gas penetration has an inverted U-

Table 2
Comparison of Factors that Influence Energy Consumption between Urban and Rural Households.

	Levels				Differences		
	Rural	Urban	City	Town	Urban-rural	City-rural	Town- rural
Dwelling characteristics							
Age of residence	17.84	13.56	13.38	14.27	−4.28***	−4.46***	−3.57***
Residential area (square meters)	149.82	110.03	105.27	128.44	−39.79 ***	−44.55 ***	−21.38 ***
Central heating (yes = 1, no = 0)	0.017	0.49	0.558	0.226	0.47***	0.54***	0.21**
Household characteristics							
Household size (number of residents)	2.936	2.541	2.546	2.523	−0.39***	0.39***	−0.41***
Annual income per capita (thousand yuan)	19.61	48.48	49.12	46.10	28.87***	29.51***	26.49***
Average age of household members	44	42	42	41	−2.48***	−2.27***	−3.19***
Education level							
Not educated	0.0461	0.0155	0.00974	0.0383	−0.03	−0.04	−0.01
Primary to middle school	0.748	0.196	0.154	0.366	−0.55***	−0.59***	−0.38***
High school	0.167	0.282	0.28	0.289	0.12*	0.11*	0.12
Bachelor or above	0.039	0.506	0.556	0.306	0.47***	0.52***	0.26***
Observations	281	1144	905	235			

Notes: The table reports the summary statistics of the factors that influence energy consumption. The first four columns summarize the dwelling and household characteristics in rural areas, urban areas, city and town, respectively. The last three columns show the differences. The significance level is indicated by stars: *** indicates 1% significance level, ** 5%, and * 10%, respectively.

Table 3
Residential energy consumption and urbanization.

	(1)	(2)	(3)	(4)
Urban dummy	0.177***	−0.086	−0.184***	−0.264***
	(0.055)	(0.064)	(0.062)	(0.081)
Age of residence		0.007***	0.007***	0.004*
		(0.002)	(0.002)	(0.002)
Log of residential area		0.186***	0.253***	0.263***
		(0.052)	(0.049)	(0.059)
Central heating		0.971***	0.969***	0.841***
		(0.068)	(0.064)	(0.084)
Household size			−0.242***	−0.231***
			(0.017)	(0.019)
Average age of members			0.006***	0.006***
			(0.001)	(0.002)
Annual income per capita			1.228***	0.649
			(0.454)	(0.558)
Squared income			−0.807***	−0.548
			(0.302)	(0.372)
Primary or middle school			−0.242***	−0.117
			(0.017)	(0.110)
High school			−0.154	−0.154
			(0.112)	(0.110)
Bachelor or above			−0.198*	−0.083
			(0.114)	(0.112)
Constant	5.632***	4.936***	5.243***	3.850***
	(0.110)	(0.296)	(0.302)	(0.324)
Observations	1425	1415	1400	1133
R-squared	0.317	0.422	0.550	0.707

Notes: Fixed Effect Models. The dependent variable is the logarithm of total energy consumption. The first three columns include province dummies, and the last column includes county dummies. The decrease in the number of observations is due to the missing values in the explanatory variables added. Specifically, there are 273 missing values for the variable *county*; these observations are therefore omitted in the county fixed effects model. Income is in units of million yuan. Robust standard errors are in parentheses. ***, **, and * indicate that the estimate is statistically significant at the 1%, 5%, and 10% significance level, respectively.

shape, with a turning point that is above most of the households in the sample. Therefore, the quadratic form of income actually indicates that income increases the gas penetration rate at a decreasing speed. Furthermore, income has little influence on coal access, holding all other conditions the same.

To investigate the intensive margin, we use the consumption quantity of each main energy type as the dependent variable, conditional on the use of that energy. We use the same specification as Column (4) in Table 3 and summarize the regression results in Table 5. For comparison, Column (1) replicates the regression results of total energy consumption from Table 3, Column (4). Columns (2) through (4) in Table 5 are for electricity, gas, and coal, respectively. They show that the consumption of electricity is sensitive to

Table 4
Penetration of Main Energy Types and Urbanization (Extensive Margin).

	(1)	(2)	(3)	(4)
	Gas		Coal	
	PLM	Logit	PLM	Logit
Urban dummy	0.239***	0.293 ***	−0.065	−0.009
	(0.048)	(0.053)	(0.051)	(0.044)
Age of residence	−0.004***	−0.005***	0.004***	0.005***
	(0.001)	(0.002)	(0.001)	(0.001)
Log of residential area	−0.016	−0.011	0.043	0.041
	(0.033)	(0.042)	(0.032)	(0.043)
Central heating	0.107**	0.096*	−0.104**	−0.201***
	(0.051)	(0.050)	(0.045)	(0.070)
Household size	0.009	0.012	0.002	0.005
	(0.011)	(0.016)	(0.011)	(0.014)
Average age of members	−0.001	−0.002	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Annual income per capita	1.506***	2.568***	−0.377*	0.415
	(0.395)	(0.682)	(0.224)	(2.142)
Squared income	−1.072***	−4.166**	0.199	−12.671
	(0.237)	(1.668)	(0.134)	(18.106)
Primary or middle school	0.015	−0.054	−0.048	0.222 ***
	(0.057)	(0.098)	(0.071)	(0.082)
High school	0.069	−0.047	−0.086	0.199 ***
	(0.061)	(0.037)	(0.073)	(0.057)
Bachelor or above	0.073	0.012	−0.114	0.153***
	(0.062)	(0.032)	(0.072)	(0.056)
Constant	0.217		−0.273	
	(0.174)		(0.170)	
Observations	1133	845	1133	622
R-squared	0.631	0.465	0.484	0.394

Notes: Probability Linear Model (PLM) and Logit model. The dependent variable is a dummy variable, which equals one if the main energy type is consumed, and zero otherwise. County dummies are included in all the columns. Income is in units of million yuan. Robust standard errors are in parentheses. ***, **, and * indicate that the estimate is statistically significant at the 1%, 5%, and 10% significance level, respectively.

almost all the household and dwelling characteristics, except the dummy variable of *urban.* In contrast, conditional on the use of coal, the quantity of coal consumed is sensitive to few factors, except for average age of household members. Combining the estimated results for the extensive (Table 4) and intensive margins (Table 5), we see that urbanization changes coal consumption mainly through changing access to coal, and that the changes in total energy consumption include the changes in both quantity and structure of energy consumption.

To investigate the total effect of urbanization on energy consumption, combining both extensive and intensive margins, we include all households, and use energy consumption, instead of logarithm of energy consumption, as the dependent variable. As many households do not use gas or coal, we employ a Tobit model to deal with the many zeros in the dependent variable of the gas and coal regressions. We report the marginal effects in Table 6.[7]

We now calculate the direct and indirect contributions of urbanization to energy consumption change. The calculation method is as follows. In previous sections, we have obtained the differences in influencing factors between urban and rural areas (Table 2), and the marginal effect of each factor on energy consumption (Table 6). By multiplying the differences and the marginal effects, we obtain the contribution of each factor to the energy consumption difference between urban and rural households. The results are presented in Table 7. It shows that urbanization decreases residential energy consumption directly through changing the external environment; urbanization also affects energy consumption indirectly through changing household and dwelling characteristics: newer houses in urban areas, smaller residential areas and younger household members reduce energy usage, while smaller household size and higher income increase energy consumption. Putting together the direct and indirect effects, urbanization results in a 118.15 kgce increase (a 27.60% increase) in energy consumption per capita, 21.14 kgce (32.18%) increase in electricity, 85.34 kgce (35.14%) increase in gas, and 58.05 kgce (96.80%) decrease in coal.

[7] The coefficient of urban dummy is not statistically significant but is economically significant (i.e. 49 kgce is about 10% of the total energy consumption of a household). The possible reason for the insignificance could be that the estimation is not sufficient. The estimates for electricity and coal are smaller than those for total energy, but the former are both statistically significant. This suggests that the insignificance could be because the total energy consumption has more noise than the consumption of a specific type of energy (e.g. urbanization has a positive impact on electricity and gas consumption and negative impact on coal consumption). If we had more data or were able to reduce the variance of the error term, we might have obtained a statistically significant estimate. Therefore, here we only conclude that, there seems to be a trend that urbanization leads to a decrease in total energy consumption. Further studies (e.g. a larger sample size) are needed to verify it.

Table 5
Consumption of main energy types and urbanization (intensive margin).

	(1)	(2)	(3)	(4)
	Total	Electricity	Gas	Coal
Urban dummy	−0.264***	0.126	0.164	−0.506
	(0.081)	(0.083)	(0.219)	(0.465)
Age of residence	0.004*	−0.004**	−0.002	−0.024
	(0.002)	(0.002)	(0.006)	(0.020)
Log of residential area	0.263***	0.154**	−0.058	−0.791*
	(0.059)	(0.060)	(0.133)	(0.461)
Central heating	0.841***	−0.047	0.044	1.364
	(0.084)	(0.098)	(0.255)	(1.765)
Household size	−0.231***	−0.268***	−0.166***	−0.072
	(0.019)	(0.021)	(0.054)	(0.100)
Average age of members	0.006***	−0.003	0.005	0.027***
	(0.002)	(0.002)	(0.005)	(0.010)
Annual income per capita	0.649	1.954***	1.533	−2.225
	(0.558)	(0.659)	(1.205)	(22.585)
Squared income	−0.548	−1.200***	−1.003	109.306
	(0.372)	(0.393)	(0.766)	(197.809)
Primary or middle school	−0.117	0.288**	−0.551**	−0.314
	(0.110)	(0.112)	(0.215)	(0.281)
High school	−0.154	0.322***	−0.597**	−0.534
	(0.110)	(0.118)	(0.261)	(0.370)
Bachelor or above	−0.083	0.398***	−0.640***	−2.073
	(0.112)	(0.117)	(0.222)	(1.856)
Constant	3.850***	3.329***	5.039***	5.052
	(0.324)	(0.321)	(0.870)	(3.333)
Observations	1133	1133	922	159
R-squared	0.707	0.492	0.327	0.740

Notes: County Fixed Effect Models. Dependent variable is the logarithm of electricity/gas/coal consumption. Taking the logarithm automatically drops households with zero consumption. The regressions in this table, therefore, investigate the intensive margin of urbanization on energy type. Income is in units of million yuan. Robust standard errors are in parentheses. ***, **, and * indicate that the estimate is statistically significant at the 1%, 5%, and 10% significance level, respectively.

4. Simulation

In this section, we simulate the change of energy consumption from 2012 to 2020 that can be expected due to urbanization. We consider two scenarios: urbanization only, and urbanization plus population growth. Results are depicted in Fig. 4.

We first forecast the number of households that will have migrated to urban areas between 2012 and 2020, using the goals set in China's urbanization plan and the population growth forecast from "the 13th Five-Year Plan for the Economic and Social Development of the People's Republic of China". In 2012, the urbanization rate was 52.57% and the total population was 1.35 billion. The urbanization rate is expected to reach 60% and the total population is forecast to be 1.42 billion in 2020, according to the 13th Five-Year Plan.

We then put together the regression results from the previous section and the migration forecast to simulate the change of energy consumption due to urbanization.[8] We multiply *change in urbanization rate* with *population* and *energy change* per capita, and obtain 11.85 million tons of standard coal equivalent increase in total energy consumption. Using the same method, electricity, gas, and coal consumption changes are forecasted to be 2.120 million, 8.560 million, and −5.823 million tons of standard coal. Given that total energy, electricity, gas, and coal consumed by households in 2012 were 423.81 million, 76.61 million, 15.22 million and 124.26 million tons of standard coal, the consumption structure change due to urbanization is economically significant.

Next, we simulate the energy consumption change considering both urbanization and population growth. The consumption changes are forecasted to be 46.78, 7.61, 16.13, and −6.47 million tons of standard coal for total residential energy, electricity, gas, and coal, respectively. The changes are about four-fold the changes without considering population growth. This indicates that population growth is a strong force in increasing energy consumption.

Given that the urbanization rate and the population growth vary across provinces, we further simulate the spatial distribution of energy consumption changes caused by urbanization from 2012 to 2020. The results are depicted in Fig. 5. The left upper figure forecasts that residential energy consumption will increase in most of the provinces except Heilongjiang and Jilin. Energy

[8] It tends to over-interpret the data when we use a non-significant coefficient in the following simulation. However, without showing the total energy trend, the specific energy trends tend to suggest a positive total energy trend, because the table shows that the increase in electricity and gas is larger than the decrease in coal. But this is a misunderstanding, as there are other energy types that are included in total energy but not specified out in this paper, such as biomass energy. Biomass energy tends to decrease so much with urbanization that, together with coal, the decrease is likely to offset the increase in electricity and gas. That's likely why we find a decreasing trend in total energy.

Table 6
Consumption of total residential energy and main energy types.

	(1)	(2)	(3)	(4)
	Total	Electricity	Gas	Coal
Urban dummy	−48.991	16.902**	116.378***	−10.930***
	(41.437)	(6.798)	(34.267)	(3.229)
Age of residence	2.469**	−0.137	−1.259*	0.833***
	(1.208)	(0.221)	(0.663)	(0.097)
Log of residential area	224.790***	21.402***	46.580*	10.477***
	(46.274)	(6.700)	(25.468)	(0.615)
Central heating	389.535***	−9.228	−74.439	−61.014***
	(53.573)	(8.944)	(45.415)	(4.014)
Household size	−130.045***	−23.415***	−25.639***	−2.303***
	(15.794)	(2.424)	(8.270)	(0.783)
Average age of members	4.565***	−0.246	0.350	0.967***
	(1.051)	(0.176)	(0.655)	(0.059)
Annual income per capita	827.663*	200.660**	165.571	207.579***
	(456.282)	(93.206)	(213.640)	(70.387)
Squared income	−675.698**	−134.999**	−192.543	−1716.57***
	(305.358)	(54.731)	(173.151)	(335.955)
Primary or middle school	−11.689	24.637**	−36.987	−11.855***
	(66.782)	(10.124)	(27.555)	(2.449)
High school	−110.922	30.693***	−38.253	−31.070***
	(72.546)	(11.193)	(26.983)	(2.662)
Bachelor or above	−67.956	29.164***	−30.782	−79.975***
	(70.329)	(10.830)	(27.912)	(3.462)
Constant	548.909**	2.994	−162.699	−396.127***
	(252.087)	(39.849)	(152.451)	(3.063)
Observations	1133	1133	1133	1133

Notes: Tobit model with county fixed effects. The dependent variable is the quantity of energy consumed. Income is in units of million yuan. Robust standard errors are in parentheses. ***, **, and * indicate that the estimate is statistically significant at the 1%, 5%, and 10% significance level, respectively.

Table 7
Direct and indirect contributions of urbanization to residential energy consumption change.

	(1)	(2)	(3)	(4)
	Total Energy	Electricity	Gas	Coal
Urban dummy	−48.991	16.902	116.378	−10.930
Age of residence	−10.567	0.586	5.389	−3.565
Residential area	−65.815	−6.266	−13.638	−3.067
Central heating	183.977	−4.358	−35.158	−28.817
Household size	51.368	9.249	10.127	0.910
Average age of members	−9.130	0.492	−0.700	−1.934
Annual income per capita	17.309	4.535	2.941	−10.648
Total change	118.151	21.139	85.340	−58.052
Percent change	27.60%	32.18%	35.14%	−96.80%

Notes: Energy consumption change is obtained by multiplying the difference in the factor between urban and rural households (summary in Table 2) and the effect of the factor on energy consumption (result in Table 6). Because the number of years of education is not likely to change with urbanization in a short run, education is not included in the calculation of contribution of influencing factors.

consumption in Shandong, Guangdong, and Hebei will have the largest growth, followed by the provinces in eastern and central China. The right upper and left lower figures show that the spatial distributions of electricity and gas consumption changes will be similar to that of the total residential energy change. As for coal (shown in the right lower figure), most provinces are forecasted to have a decrease in coal consumption. The area with the most decrease in coal consumption will be the region around the Bohai Sea (e.g., Hebei and Shandong provinces) and parts of central and western China (e.g., Henan and Sichuan provinces). These patterns are in line with population distribution and migration patterns, as population and out-migration concentrate in these areas.

5. Onsite and offsite urbanization

As discussed above, in offsite urbanization, rural residents migrate to cities; in onsite urbanization, rural areas convert to towns. Because the characteristics of households, dwellings, and external environment are different between cities (offsite) and towns (onsite), rural households that migrate to cities may have different energy-using behavior and form different energy consumption

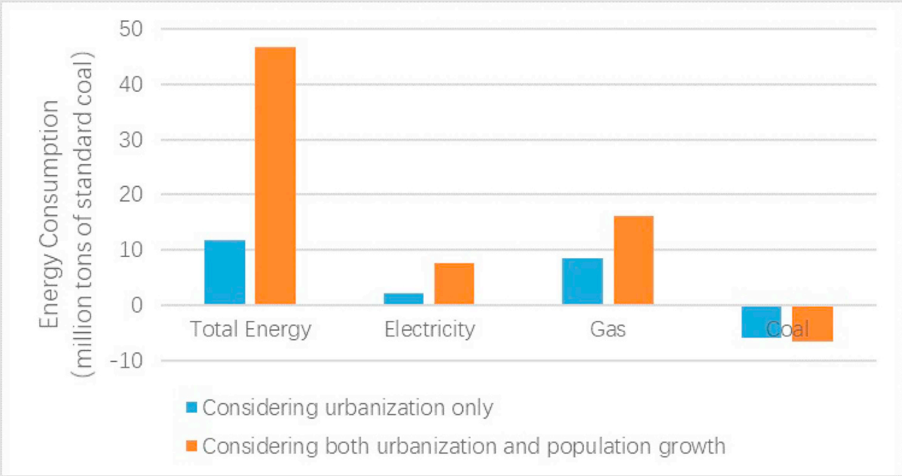


Fig. 4. Forecasted Change of Residential Energy Consumption from 2012 to 2020.

habits than those that urbanize locally.

To distinguish the effects of offsite and onsite urbanization, we replicate the regressions in Table 6, with the urban dummy replaced by city dummy and town dummy. The regression results are presented in Table 8. It shows that a household located in a town consumes less energy in total compared to a similar household in a rural area (the coefficient of town dummy is −91.8 kgce, which is about 20% less and statistically significant), while a household located in a city and a similar household in a rural area consume similar amounts of energy (the coefficient of city dummy is −8.7 kgce, which is about 2% less, and not statistically significant). This suggests that offsite urbanization causes less decrease in energy consumption than onsite urbanization, conditional on the same dwelling and household characteristics. The possible reason could be that the external environment such as energy-related markets and infrastructure are more mature in large cities, which potentially induces more energy consumption and largely offsets the energy saving effect of urbanization. Next, Table 8 shows that the structure of energy consumption change is also different between onsite and offsite urbanization. Compared to onsite urbanization, offsite urbanization shows a larger structural shift from coal to gas and electricity. When we further estimate the impacts of onsite urbanization and offsite urbanization on extensive and intensive margins (results are summarized in Tables A2 and A3 in the appendix), we find that for the three disaggregated energy consumption, both extensive and intensive margins of offsite urbanization are larger than onsite urbanization; The positive effect of offsite urbanization on gas is so large that it almost fully offsets the energy saving effect, and it therefore leads to a small and not significant decrease effect on total energy consumption (i.e., the coefficient of offsite urbanization is small and not statistically significant in Column 1 of Table 8).

Table 9 simulates the energy consumption changes caused by the two forms of urbanization. It shows that offsite urbanization increases per capita residential energy consumption by 167.13 kgce, while onsite urbanization reduces per capita residential energy consumption by 14.65 kgce. The main difference comes from the contribution of the urban dummies to energy consumption; these are −8.71 and −91.84 for city dummy and town dummy respectively. Among the main energy types, the urban dummy differs significantly for gas; the city dummy is 144.7 and the town dummy is 77.33. This indicates that the change in the external environment from rural to city increases consumption of gas more than the change from rural to town. The possible reason is that the infrastructure for gas consumption is better in cities than in towns.

6. Conclusion

In this paper, we study the effect of urbanization on residential energy consumption. We find that the key driving factors behind the difference in energy consumption between urban and rural households include both household and dwelling characteristic (e.g., dwelling age and size, household income, size and education, etc.) as well as unobservable factors (e.g., external environment, energy-saving consciousness, and living habits). Urbanization could affect residential energy consumption directly through changing the external environment and indirectly through changing household and dwelling characteristics. Compared to rural households, urbanized households earn more, live in smaller spaces, and make different choices in consumption and lifestyle.

We find that urbanization increases the quantity of residential energy consumption. We also find that urbanization improves gas accessibility and reduces the portion of households that use coal. Conditional on the use of coal, the intensive margin of urbanization on coal consumption is small. That is, urbanization changes the structure of energy consumption by increasing the consumption of electricity and gas and decreasing the portion of households that use coal.

Putting together the direct and indirect effects, we find that urbanization leads to a 28% increase in per capita energy consumption, including a 32% increase in electricity, a 35% increase in gas, and a 98% decrease in coal. By simulating the energy consumption change considering both urbanization and population growth, we forecast that from 2012 to 2020, consumption of

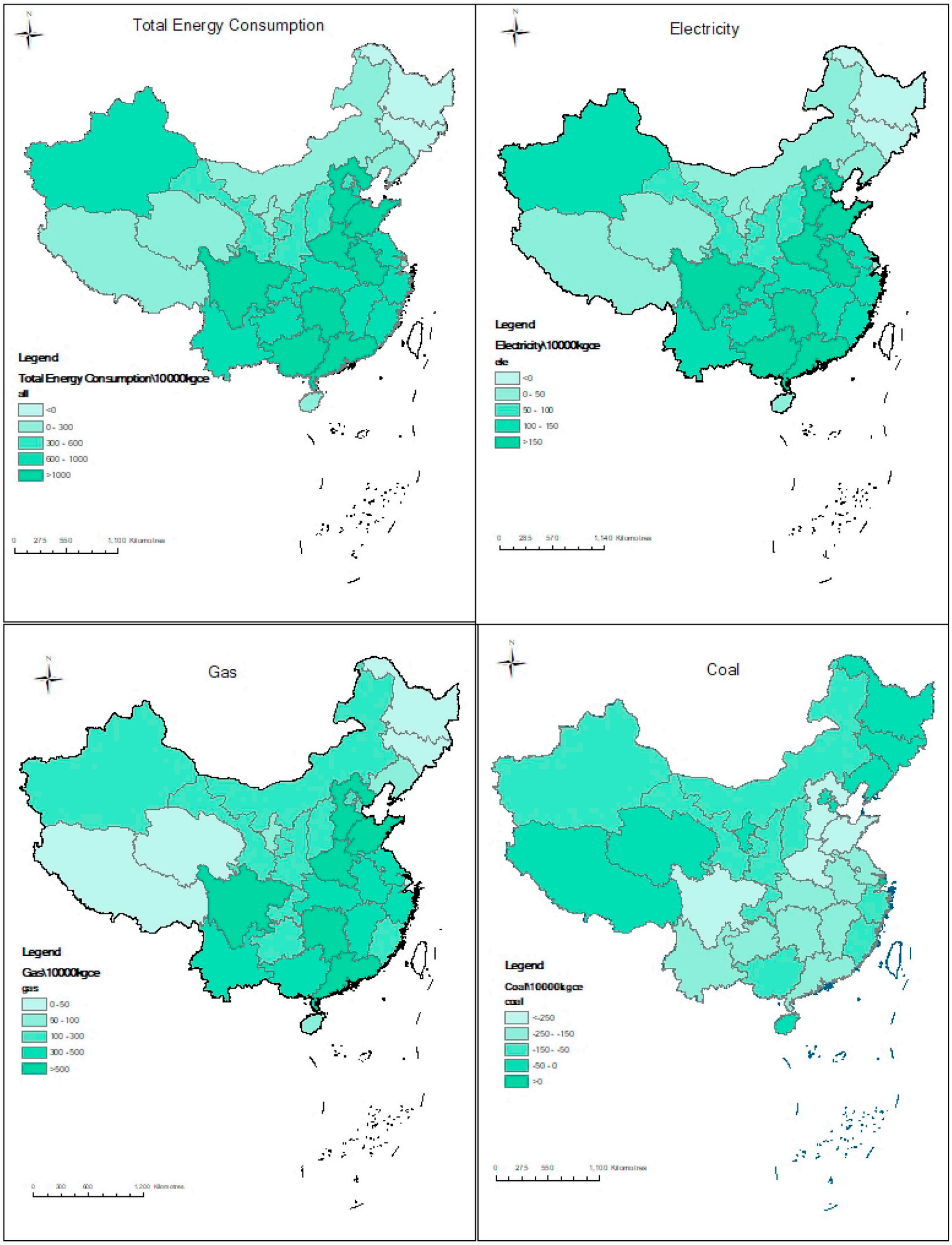


Fig. 5. Spatial Distribution of Residential Energy Consumption Changes from 2012 to 2020 Induced by Urbanization.

residential energy, electricity, and gas will increase by 47, 7.6, and 16 million tons of standard coal, respectively, while coal will decrease by 6.5 million tons of standard coal.

Looking into the spatial distribution of energy consumption changes induced by urbanization, we expect to see that most provinces have an increase in the consumption of total residential energy, electricity and gas, and a decrease in the consumption of coal. The area with the most decrease in coal consumption will be the region around the Bohai Sea and parts of central and western China, where the population and out-migration concentrate.

In the process of urbanization, either rural households migrate to cities (offsite urbanization) or rural areas become towns (onsite urbanization). We find that offsite urbanization (moving to cities) increases energy consumption substantially, while onsite

Table 8
Onsite and offsite urbanization and energy consumption.

	(1)	(2)	(3)	(4)
	Total	Electricity	Gas	Coal
City dummy	−8.708	20.861**	144.702***	−23.147***
(offsite urbanization)	(46.667)	(8.317)	(35.045)	(3.867)
Town dummy	−91.843**	12.690	77.333*	−3.991
(onsite urbanization)	(44.473)	(7.945)	(39.694)	(3.256)
Age of residence	2.487**	−0.136	−1.239*	0.832***
	(1.205)	(0.220)	(0.660)	(0.098)
Log(residential area)	229.685***	21.883***	49.695*	8.704***
	(46.397)	(6.671)	(25.371)	(0.617)
Central heating	371.640***	−10.986	−86.656*	−54.421***
	(54.081)	(9.143)	(46.577)	(4.441)
Household size	−130.505***	−23.460***	−26.161***	−2.322***
	(15.856)	(2.425)	(8.327)	(0.786)
Average age of members	4.567***	−0.245	0.336	0.943***
	(1.052)	(0.176)	(0.651)	(0.059)
Annual income per capita	779.493*	195.924**	127.707	214.983***
	(451.014)	(92.970)	(211.286)	(71.091)
Squared income	−640.180**	−131.507**	−164.292	−1735.63***
	(303.616)	(54.645)	(173.663)	(342.774)
Constant	−20.495	23.771**	−42.343	−10.828***
	(66.346)	(10.098)	(27.675)	(2.456)
Observations	1132	1132	1132	1132

Notes: Tobit Model. County dummies are included. Education dummies are included but not reported. Income is in units of million yuan. Robust standard errors are in parentheses. ***, **, and * indicate that the estimate is statistically significant at the 1%, 5%, and 10% significance level, respectively.

Table 9
Energy consumption change caused by onsite and offsite urbanization.

	Offsite urbanization				Onsite urbanization			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Total	Electricity	Gas	Coal	Total	Electricity	Gas	Coal
Urban dummy	−8.708	20.861	144.702	−23.147	−91.843	12.690	77.333	−3.991
Age of residence	−11.092	0.607	5.526	−3.711	−8.879	0.486	4.423	−2.970
Residential area	−74.877	−7.134	−16.201	−2.838	−36.520	−3.479	−7.902	−1.384
Central heating	200.797	−5.936	−46.820	−29.404	77.413	−2.288	−18.050	−11.336
Household size	50.897	9.149	10.203	0.906	53.899	9.689	10.804	0.959
Average age of members	−9.134	0.490	−0.672	−1.886	−13.701	0.735	−1.008	−2.829
Annual income per capita	19.245	5.017	2.830	−3.853	4.979	2.006	−0.534	−36.889
Total change	167.128	23.055	99.568	−63.932	−14.653	19.838	65.067	−58.440
Percentage change	39.04%	35.09%	41.00%	−106.61%	−3.42%	30.19%	26.79%	−97.45%

Notes: Energy consumption change is obtained by multiplying the difference in the factor between urban households (city for offsite urbanization and town for onsite urbanization) and rural households and the effect of the factor on energy consumption. Because the number of years of education is not likely to change with urbanization, education is not included in the calculation of contribution of influencing factors.

urbanization (formation of towns) reduces energy consumption slightly. We also find that the structure of the energy consumption change will be different between offsite and onsite urbanization. Compared to onsite urbanization, offsite urbanization will be associated with a larger structural shift from coal to gas and electricity.

Based on the findings, policy makers could accordingly adjust energy plans, environmental protection, and carbon reduction tasks. Since urbanization is likely to shift the energy structure from coal to electricity and gas, the challenge of the energy transition is reduced, especially in the areas of Bohai Sea and central and western China. However, the pressure on gas supply is likely to increase accordingly. Meanwhile, the environmental pressure could be less, because gas is cleaner than coal, and emissions from coal-fired power plants are easier to deal with, compared to household coal. However, the effect of urbanization on carbon reduction could be ambiguous, because more than 60% of power plants in China are coal-fired power plants. Carbon is released through coal combustion independent of combustion methods. Therefore, the effects of urbanization on environment and carbon emission could be the direction of future research.

Notes: The surveyed households are randomly sampled, covering 95 prefecture-level or above cities from 27 provinces in mainland China, omitting Jiangsu, Tibet, Qinghai and Shaanxi.

Notes: The forecasted changes of total energy consumption, electricity, gas and coal are depicted. The results in the scenario of considering urbanization only and the scenario of considering both urbanization and population growth are compared.

Notes: Based on the regression results and the changes of population and urbanization in each province in mainland China, we simulate the spatial distribution of the change of residential energy consumption as well as electricity, gas and coal in each province.

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Appendix A. Appendix

Table A1
Conversion coefficients and energy consumption per capita.

Energy	No. of obs.	Conversion coefficient	Physical quantity		Standard quantity (unit: kgce)		
			Mean	Unit	Mean	Min	Max
Electricity	1425	0.123	771.626	kWh	94.91	2.219	1016
Central heating	1425	1	289.2	kgce	289.2	0	10,432
Coal	1425	1.33	4.881955	kg	6.493	0	489.7
LPG	1425	0.357	108.0952	m3	38.59	0	1238
Natural gas	1425	0.357	294.6779	m3	105.2	0	2731
Biomass energy	1425	0.714	100.6162	m3	71.84	0	2398
Solar energy	1425	1	0.0452	kgce	0.0452	0	0.903

Notes: The physical quantities are collected from CRECS 2012. The standard quantities are calculated using conversion coefficients from the China Energy Statistical Yearbooks.

Table A2
Penetration of main energy types and onsite and offsite urbanization (extensive margin).

	Gas		Coal	
	(1)	(2)	(3)	(4)
	PLM	Logit	PLM	Logit
City dummy	0.315***	0.338***	−0.107**	−0.085
(offsite urbanization)	(0.053)	(0.057)	(0.053)	(0.059)
Town dummy	0.159***	0.220***	−0.021	0.039
(onsite urbanization)	(0.051)	(0.062)	(0.056)	(0.051)
Age of residence	−0.004***	−0.005***	0.004***	0.004***
	(0.001)	(0.002)	(0.001)	(0.001)
Log(residential area)	−0.007	−0.003	0.037	0.028
	(0.033)	(0.043)	(0.031)	(0.043)
Central heating	0.074	0.077	−0.085*	−0.166**
	(0.051)	(0.050)	(0.044)	(0.074)
Household size	0.008	0.011	0.002	0.006
	(0.011)	(0.016)	(0.010)	(0.014)
Average age of members	−0.001	−0.002	0.001	0.000
	(0.001)	(0.001)	(0.001)	(0.001)
Annual income per capita	1.415***	2.419***	−0.328	0.669
	(0.385)	(0.687)	(0.223)	(2.140)
Squared income	−1.005***	−3.863**	0.162	−14.131
	(0.233)	(1.674)	(0.135)	(18.084)
Constant	−0.338		0.924***	
	(0.218)		(0.203)	
Observations	1132	845	1132	622
R-squared	0.635	0.471	0.486	0.400

Notes: Probability Linear Model (PLM) and Logit model. The dependent variable is a dummy variable, which equals one if the main energy type is consumed, and zero otherwise. County dummies are included in all columns. Income is in units of million yuan. Robust standard errors are in parentheses. ***, **, and * indicate that the estimate is statistically significant at the 1%, 5%, and 10% significance level, respectively.

Table A3
Consumption of main energy types and onsite and offsite urbanization (intensive margin).

	(1)	(2)	(3)	(4)
	Total	Electricity	Gas	Coal
City dummy	−0.257***	0.182**	0.292	−1.042
(offsite urbanization)	(0.089)	(0.092)	(0.211)	(0.734)
Town dummy	−0.271***	0.066	−0.044	−0.479
(onsite urbanization)	(0.092)	(0.093)	(0.266)	(0.481)
Age of residence	0.004*	−0.004**	−0.002	−0.024
	(0.002)	(0.002)	(0.006)	(0.020)
Log(residential area)	0.264***	0.160***	−0.045	−0.820*
	(0.060)	(0.060)	(0.132)	(0.473)
Central heating	0.838***	−0.072	−0.004	1.916
	(0.087)	(0.097)	(0.257)	(2.073)
Household size	−0.231***	−0.269***	−0.169***	−0.067
	(0.019)	(0.021)	(0.054)	(0.102)
Average age of members	0.006***	−0.003	0.005	0.027***
	(0.002)	(0.002)	(0.005)	(0.010)
Annual income per capita	0.641	1.887***	1.348	−2.016
	(0.562)	(0.657)	(1.179)	(22.694)
Squared income	−0.542	−1.150***	−0.864	106.928
	(0.376)	(0.393)	(0.753)	(198.326)
Constant	4.424***	4.569***	4.426***	3.917
	(0.406)	(0.391)	(0.982)	(3.118)
Observations	1132	1132	922	159
R-squared	0.703	0.492	0.329	0.740

Notes: County Fixed Effect Models. Dependent variable is the logarithm of electricity/gas/coal consumption. Taking the logarithm automatically drops households with zero consumption. The regressions in this table, therefore, investigate the intensive margin of urbanization on energy type. Income is in units of million yuan. Robust standard errors are in parentheses. ***, **, and * indicate that the estimate is statistically significant at the 1%, 5%, and 10% significance level, respectively.

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