Socioeconomic impacts on residential demand for electrical services in China

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Abstract: Understanding the residential demand for various energy services is critical for utilities and policymakers for effective demand-side management. However, the practices usually treat the household as an analysis unit, thus may ignore the fact that the electricity consumption is induced demand driven by specific services. This study presents the pattern of various residential demand for electrical service and qualifies the impact of socioeconomic determinants in China. The conditional demand analysis model is performed on the unique dataset of Chinese Residential Energy Consumption Survey 2014 to estimate the electricity demand distribution of eight types services and investigate behavioral responses of socioeconomic variables to service-specific electricity consumption. It shows that both entertainment and fresh keeping services account for about half of the total annual electricity consumption, followed by laundry, lighting, space cooling, and hot water. Rural households use about 7.2% of total electricity for cooking purpose while urban counterparts hardly use electricity to cook. Electricity consumption is negligible for space heating for both urban and rural households. The heterogeneity in socioeconomic determinants are found not only among different electrical services but also between urban and rural households.

Keywords: Chinese residential sector; electrical service-specific electricity consumption; socioeconomic determinants; heterogeneous responses; conditional demand analysis

1. Introduction

Residential electricity consumption is increasingly important for global decision-makers under the sustainability constraint, especially confronted with the 2-degree Celsius limit. The residential sector worldwide consumed around 27% of the total final electricity demand in 2018 (IEA, 2020). Thus, it constitutes a significant realm to examine residents' electricity-consuming behavior and form effective demand side management policies, to alleviate energy shortage and reduce the pollutant discharge and massive CO_2 emissions brought by electricity generation.

Previous studies made great effort on residential electricity demand analysis by utilizing sectoral statistics data in certain region or nation (Kamerschen and David, 2004; Halicioglu, 2007; Auffhammer and Wolfram, 2014). Benefit with recent microdata, there emerge increasingly studies using household surveyed or metered consumption data to estimate price elasticity and income elasticity (Reiss and White, 2005; Bernard et al., 2011; Hung and Huang, 2015), to assess how residents respond to demand side management policies (Wolak 2011; Rapson, 2014; Muratori, 2018), to help scholars better understand how different socioeconomic variables, dwelling characteristics, and climatic conditions affect electricity use (Brounen et al., 2012; Ruijven et al., 2019; Li et al., 2019). However, specific demand patterns of electrical services within the household has not explored. In addition, the household level data may mask the different consumption behavior toward various electrical services as its implicit assumption is that the underlying influencing factors have the same effect.

Therefore, it is important and beneficial to switch from household-based analysis to service-oriented study for the following reasons. **First**, the composition of household electricity consumption constitutes an important dimension to measure family welfare and becomes a key indicator to represent the service flow and monitor the welfare change (Wu et al., 2017). Different from the aggregate household electricity consumption that fails to provide information on the detailed service composition, the different composition of services can reflect the change of family welfare even though the aggregate outcome of various demands for in-home real services does not change

(Quigley, 1984; Dubin and McFadden, 1984). **Second**, ignoring the heterogeneity of socioeconomic variables on different electrical services may seriously misguide the policy. China's society is experiencing a long-term aging process, the people's education level is constantly improving, and the residents' income continues to grow. Revealing the heterogeneous impacts of these socioeconomic variables on different electrical services can guide the policy to focus on the service areas that have significant changes in power demand, and formulate precise response to form a more cost-effective policy mix. For instance, existing studies have estimated income elasticity of total electricity consumption. However, this tends to ignore the potential heterogeneous impacts of income on different electrical services (e.g, space cooling/heating has larger income elasticity than lighting). Accordingly, policy makers should focus on specific service policies (say space heating), such as implementing replacement subsidies to improve the energy efficiency of existing service (say adopting new heating mode) instead of adopting a one-size-fits-all approach to improve the energy efficiency of all electrical appliances. The existing studies are unable to tackle this issue by using total electrical demand.

Our study echoes the call for research of the electricity demand at specific service level that helps scholars better understand consuming habits and behavior pattern of residents (Kelly and Knottenbelt, 2015), assists the utilities for designing better demand response of energy generation to improve the security of power grid (Monacchi et al., 2014), as well as guides the policy-maker to render more targeted instrument design for the demand side management (Newsham and Donnelly, 2013). We present the demand pattern covering eight types of electrical services by using a unique national-wide household survey data in China. Furthermore, we quantify the heterogeneous impacts of socioeconomic variables on different service-specific electricity demand. Our results indicate that household electricity demand from entertainment and fresh keeping services makes up around half of the total annual consumption. The services of laundry, lighting, space cooling, and hot water constitute mediocre shares. About 7.2% of total electricity is used for cooking purpose by rural households, with urban counterparts hardly using electricity to cook. Negligible electricity is used for space heating by both urban and rural households. The heterogeneity in socioeconomic determinants are unveiled not only among different electrical services but also between urban and rural households. Individual characteristics of household head mainly have significant impacts in rural area while family composition mainly shows impacts in urban area. Household income level has differential electricity-consuming behaviors in multiple services between urban and rural households.

Our paper contributes to the existing literature from three aspects. **First**, to the best our knowledge, the paper is the first one that disaggregates the total electricity consumption into service-specific level in China. This helps us better understand the electricity end-use distribution and link it to consuming habits and behavior pattern of residents. **Second**, we further investigate how household socioeconomic variables discriminately affect service-specific electricity use. This service level electricity consumption information can be served as the reference to forecast household electricity demand with specific household socioeconomic status. **Third**, the estimated service-level electricity consumption helps to identify daily activities with high energy-saving potential and to provide data support on investigating the inequality of residential electricity consumption among different groups.

2. Residential electricity consumption in China

We select China as our case for two reasons. First, as the largest energy consumer and top global CO_2 emitter, it is hard to achieve the global energy transition and climate target without China's action. Especially China has pledged to peak CO_2 emissions by 2030 and aimed to achieve carbon neutrality by 2060. This ambitious new target calls for the substantial effort from the residential sector who acts as the second largest energy user in China. Second, the wide-scale end-use electrification has been adopted as one priority strategy for climate resiliency. China not only experiences tremendous growth of residential electricity consumption, but also exists great disparity among different groups within China, i.e., the urban-rural gap. The growing, dynamic and heterogeneous China provides a unique research window and lessons for other countries.

As shown in Figure 1A, residential electricity consumption in China has grown more than tenfold over last 25 years, from about 900 TWh in 1994 to almost 10,000 TWh in 2018 with annual increase rate about 10.6%. However, as most literature have confirmed, there is great disparity in terms of economic development and other aspects between China's urban and rural area (Tao, 2012). This wide urban-rural gap also holds for the residential electricity consumption that contributes to the living standard. As the red dot-line in Fig 1A shows, the urban residents electricity consumption is about 1.3-1.4 times higher than their rural counterparties over 2008 to 2017. This disparity declines overall with rising trend in recent years.

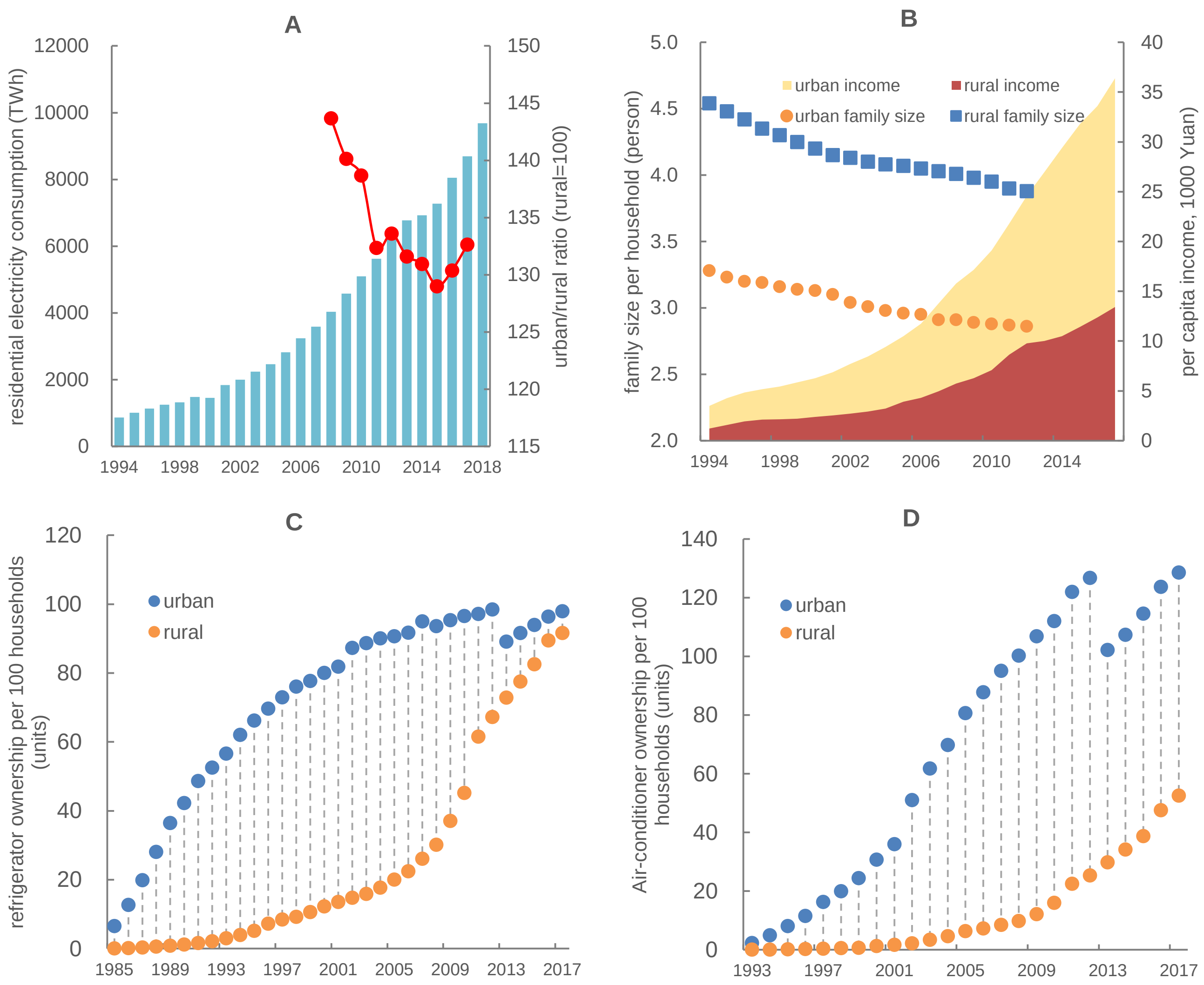

Figure 1. Development of Chinese residential sector. A) electricity consumption and urban-rural gap; B) urban-rural difference in socioeconomic variables; C) urban-rural refrigerator ownership; D) urban-rural air-conditioner ownership.

Note: Data come from China Statistical Yearbook 2019.

Figure 1B presents the family size and per capita disposable income between urban and rural households. Although family size is continuously shrinking in both urban and rural areas due to the fertility policy, the rural households have 3.9 persons on average, with almost one person more than urban counterparts. Accordingly, disposable income per capita has risen at increasing rate in both urban and rural areas, with enlarged income gap in-between.

Panel C and D at Figure 1 show the urban-rural difference of home appliance ownership. Figure 1C plots the refrigerator ownership for urban and rural residents over time. It shows that, rural households have an accelerated growth rate in owning refrigerators and converge to the level of their urban counterparts. Figure 1D shows increasing and persistent ownership gap of air-conditioner between urban and rural area, with the urban-rural difference of air-conditioner penetration rate 1.2 units/100 household in 1993 to 76 units/100 household by 2017.

3. Results and discussions

3.1. Profile of household electrical service

Our estimation first yields the overall coefficients for eight electrical services (SI Table 3 reports the detailed results). These estimated coefficients, combined with the ownership information, can be translated into the average electricity consumption for various electrical services (see SI Table 4 for details). Figure 2A, for the first time, plots an overall picture of the pattern of electrical services for a representative Chinese household who consumed 1,572 kWh in year 2014. Among all eight electrical services, the entertainment activity amounts to about 477 kWh per year, or 1.31 kWh per day, account for about 30% of electricity consumption. Fresh keeping activity is the second largest electrical usage demand. It takes 312 kWh per year (or 0.85 kWh per day) and accounts for 20% of electricity demand. Moreover, the third largest is for laundry service, which account for around 13% of electricity consumption. It follows by space cooling (12%), lighting (9%) and hot water (9%). Despite cooking is a tradition daily routine for Chinese households, it seems that the electricity penetration in cooking activities is relatively low. The cooking-related electricity consumption is only 74 kWh (or 0.20 kWh per day) across all households, which accounts for a small percentage of 5%. In addition, only about 1% of electricity is used for space heating service. It is probably due to the fact that the widely coverage/application of district heating system for northern urban residents (Guo et al., 2015).

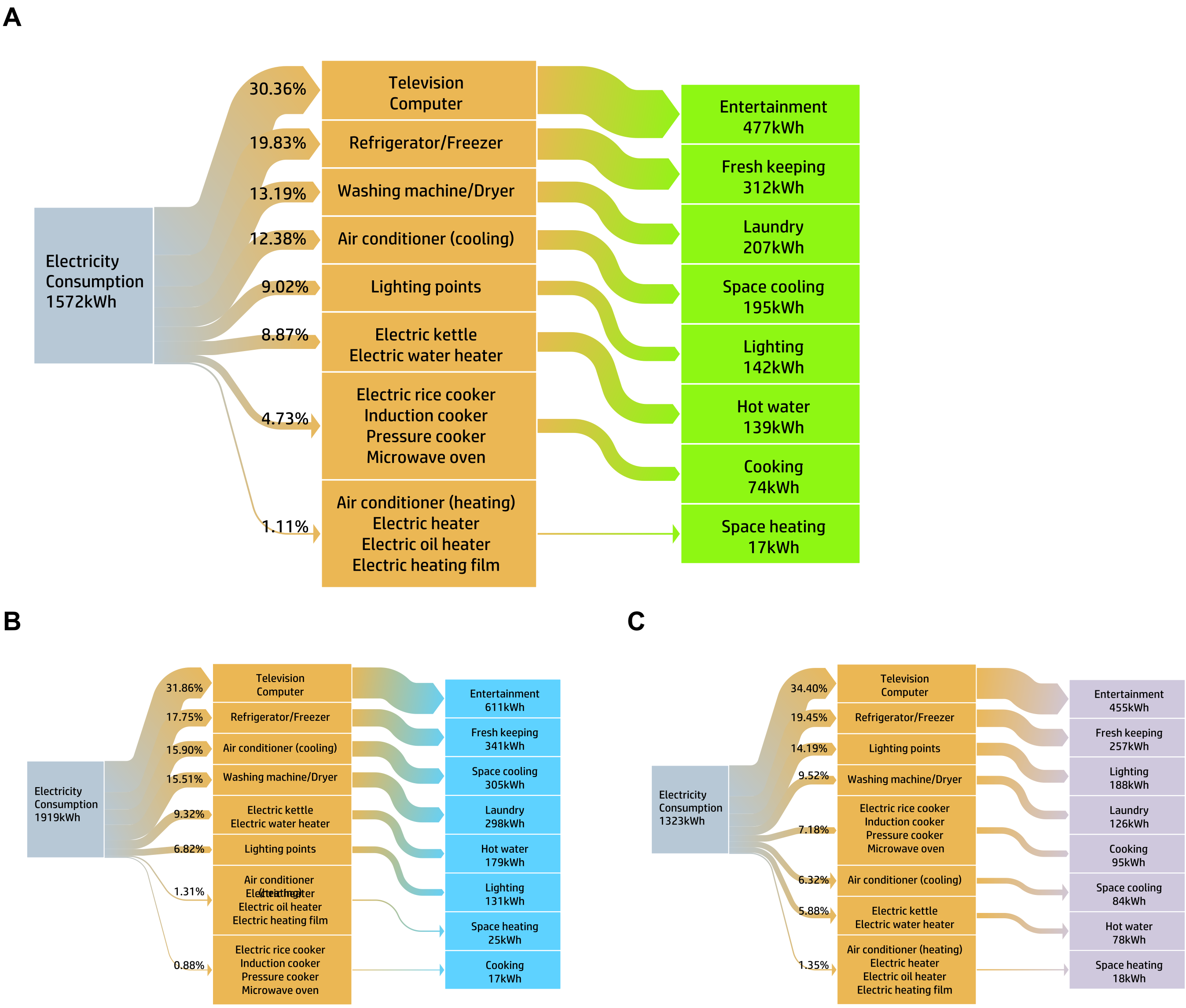

Figure 2. Profile of electrical services flow chart A) for a representative Chinese household; B) urban household; C) rural household.

Figure 2B and 2C demonstrate the urban-rural disparity of household demand for electrical services. Overall, urban residents have greater demand than rural household in terms of major electrical services, except for the cooking and lighting. On average, urban households consume 1,919 kWh electricity to meet their demand, which is 45% higher than rural residents (1,323 kWh). For urban households, four types of end-use activities (entertainment, fresh keeping, space cooling and laundry) account for more than 80% of total electricity demand. As for rural residents, the demand for four end-use purposes (entertainment, fresh keeping, lighting and laundry) contributes 78% of total electricity usage. Another noticeable difference is the demand for space cooling service. Simply assuming there is uniform three-month summer cooling period and power capacity for air-conditioner is 1 kW for both urban and rural households. Then the urban household uses 305 kWh (equivalent to 3.39 kWh per day, or 3.39 cooling hours per day) for space cooling, accounting for 15.9% of total electricity consumption. But the rural residents only use 84 kWh (translate to 0.93 kWh per day or 0.93 cooling hours per day) for cooling purpose, which accounts for 6.3% of their electricity consumption. Furthermore, the big difference in electricity usages lies in lifestyle and alternative resources. For example, urban households consume about 2.3 times higher electricity than rural counterparts in terms of laundry (298 vs 126 kWh/year) and hot water services (179 vs 78 kWh/year).

3.2. Impact of socioeconomic variables on electrical services

Figure 3 examines the effect of six socioeconomic variables on eight types of demand for electrical services, which are derived from the interaction items in CDA model (see results in SI Table 3).

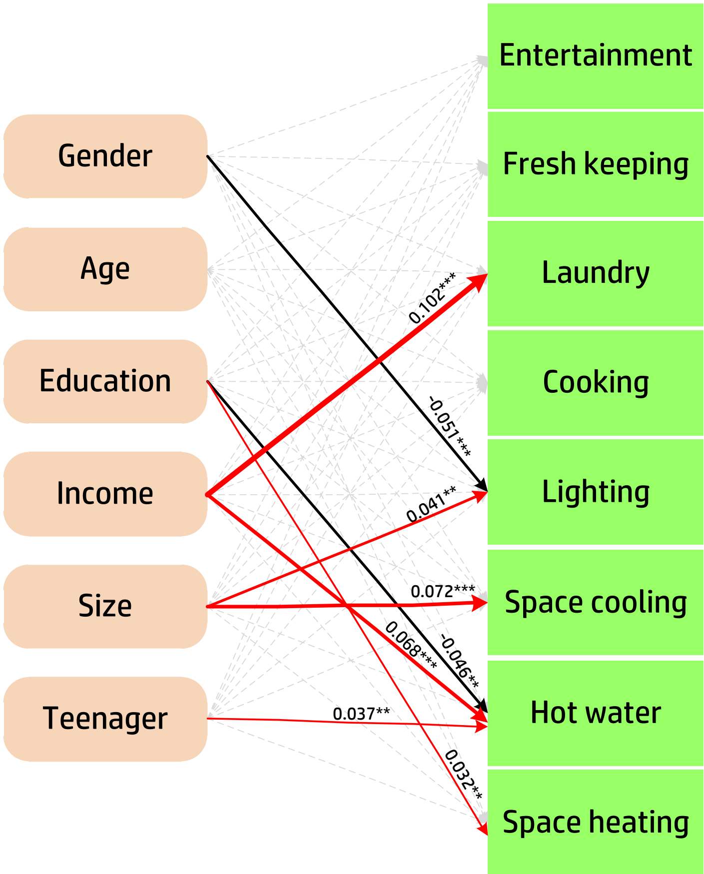

Figure 3. Socioeconomic impacts on eight services in China.

Note: The numbers in figures are standardized coefficients. The red and black line indicates positive and negative correlation, while the thickness of line indicates the effect size. ** and *** represent 5% and 1% statistic significant level, respectively.

Figure 3 presents socioeconomic heterogeneous effects on each service. Specifically, higher household income significantly pushes up electricity demand for laundry service. As with lighting service, females tend to exhibit better electricity-saving behavior than males. In addition, the larger the family size, the more electricity needed for lighting. The positive significant relationship of the family size also holds for electrical service of space cooling. For hot water service, more affluent households and households with teenagers tend to consume more electricity, while household head with higher education significantly lowers the demand for this purpose. This may be related to the bath need of different degrees of physical movement. Finally, we do see higher educated owners spend more electricity for space heating. On the nationwide perspective, electrical services of entertainment, fresh keeping, and cooking are not significantly impacted by socioeconomic variables.

3.3. Heterogeneous urban-rural effect on electrical services

We further distinguish the heterogeneous effects of socioeconomic variables on electrical services by urban and rural area. This helps us to understand better the major driving forces and precisely identify the intervention targeting object. The results are reported at Figure 4.

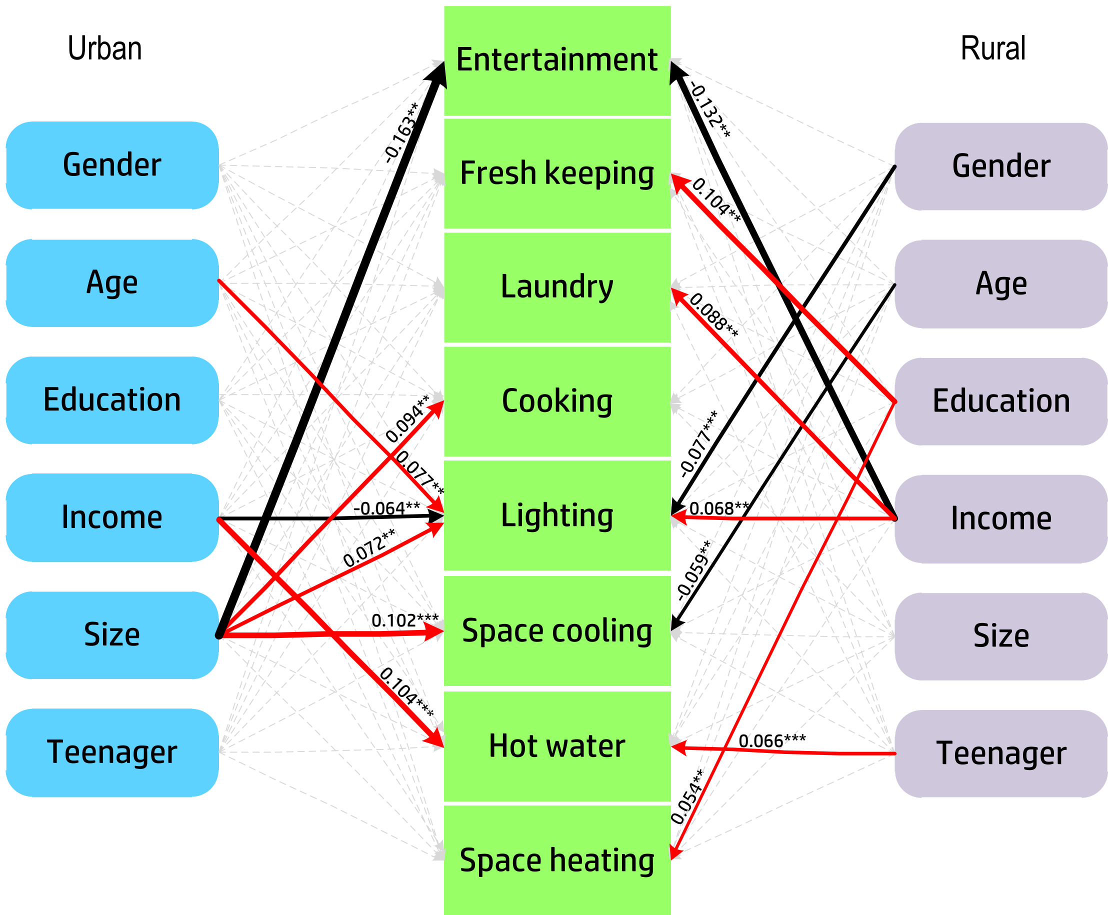

Figure 4. Socioeconomic effects on eight electrical services by urban and rural area.

Note: The numbers in figures are standardized coefficients. ** and *** represent 5% and 1% statistic significant level, respectively.

Regarding socioeconomic determinants of electricity demand for services, the obvious heterogeneity can be found between urban and rural households. Overall, individual characteristics of household head (gender, age, and educational level) have significant impacts mainly in rural households while family composition (family size and having teenagers or not) has impacts mainly in urban households. Household income variable has scattered and irregular significant impacts on both urban and rural households.

In terms of entertainment service, the larger the family size, the less electricity spent by urban households on television or computer. The increase in family size may lead to more interaction between family members, correspondingly decreasing entertainment requirement from television or computer. In rural area, household income has negative significant impact on entertainment power demand. This may result from the different lifestyle related to wealth that the rich family are more likely to afford the luxury outdoor entertainment activity (Yue, 2006).

As with electrical service for fresh keeping, only educational level of household head in rural area has positive significant impact on electricity demand. More years of education render residents learn more about the importance of keeping food fresh for physical health and thus probably push electricity demand for fresh keeping purpose.

As for laundry service, only household income in rural area has positive significant impact on electricity consumption. Higher income makes for using washing machine to replace physical labor of hand washing clothes.

Concerning electricity demand for cooking service, more family members mean higher frequency use of electrical devices for cooking, leading to significant higher consumption of electricity by urban households.

With regard to lighting service, in rural area, females tend to have better electricity-saving habit than males. In urban area, the younger the residents, the less electricity consumed for lighting purpose. What's more, the larger the family size, the more electricity is consumed. Household income has opposite significant impact on urban households and rural households. It means that more affluent households and less affluent households distinguished by mean household income show different behaviors of electricity demand for lighting purpose between urban and rural households. Specifically, in urban area, the wealthier the household, the less electricity consumed. But in rural area, the wealthier the household, the more electricity consumed. It suggests that rural households are likely to increase their usage time of relatively inferior energy efficient lighting devices with the increase of household income while urban households lower electricity demand for lighting because of higher affordability for bettering lighting efficiency.

With respect to space cooling service provided by air conditioner, different single variable has significant impact on urban and rural households. In rural area, the elderly the people, the less electricity consumed. In urban area, the larger the family size, the higher electricity demand for this purpose.

As to electricity demand for hot water, having teenagers in rural area pushes demand for hot water, probably due to higher need frequency for bathing. But only household income significantly increases electricity consumption for this purpose in urban area.

Concerning electrical space heating, only household head with higher education increases electricity consumption for this purpose in rural area while no socioeconomic variables have significant impact in urban area.

4. Conclusion

This paper estimates the electricity demand distribution of eight appliance-services and investigates how socioeconomic variables affect electricity demand of each service in China by using the unique household-level dataset of Chinese Residential Energy Consumption Survey 2014. Specifically, we report quantitatively household electricity demand composition across appliance-services and identify the impact of socio-economic variables on each of electrical service. Further, we conduct sub-group analysis of urban and rural area to dig further the similarities and differences for precise policy formulation. These findings have important policy implications to reach the goal of CO_2 reduction in China shown below in order.

First, our findings indicate that, government policy should focus on the surge in household total electricity consumption and be directed more in terms of space heating that has huge potential in the near future. Compared with other advanced economy, Chinese household average electricity consumption in 2014 only amounts to 46.9% of the world average, 43.7% of the European Union, and 12.8% of the US (World Energy Council, 2014). Besides, electricity demand for space heating in Chinese households is tiny in comparison with developed economies having similar climate conditions to China (Fiebig and Bartels, 2000; Newsham and Donnelly, 2013; Matsumoto, 2016). Our overall findings suggest that, household electricity demand from entertainment and fresh keeping services makes up around half of the total annual consumption. Further we have found electrical services of entertainment and fresh keeping are not significantly impacted by socioeconomic variables. This requires a national policy to be placed on how to meet this large electricity demand with clean energy supply. On the other hand, our findings show that the improvement of residents' education level will increase the residents' electricity demand and the growth potential is mainly in the electrical services of space heating. The increase of household income will increase the electricity demand in the electrical services of laundry and hot water. The aging population only increases the power demand of the residential sector through the service of space heating. Given that fact that China is experiencing and will be in the stage of population aging, continuous improvement of residents' education level and household income over the long-term period, government shall conduct demand side management policies to address these substantial changes in these socio-economic variables and their significant impacts on the overall electricity demand.

Secondly, energy provider and policy makers shall recognize the urban-rural gap of energy demand and the heterogeneous impacts of socioeconomics factors. Our findings indicate urban households spend significant higher proportion of electricity consumption for laundry, space cooling, and hot water than their rural counterparts. On the contrary, rural households consume significant higher share of electricity in terms of lighting service. About 7.2% of total electricity is used for cooking purpose by rural households, with urban counterparts hardly using electricity to cook. However, urban and rural residents share common usage habit in terms of space cooling and negligible electricity is used for this purpose Further, the heterogeneity in the adjustment of socioeconomic variables to urban and rural residents' electricity service demand is also an important consideration in policy-making. The improvement of residents' education level and the increase of household income level will significantly increase the power demand of rural households for fresh keeping, laundry, and lighting services while it will increase the power service demand of urban households for cooking. More importantly, the electrical service of space heating is bound to increase in both urban and rural areas. But the increase is driven by the improvement of household income level and residents' education level in urban area and rural area respectively. The heterogeneity shows that it matters to make more appropriate policy objectives and tailor-made implementation measures for differential electricity growth potentials in urban and rural areas in China.

Finally, this study sheds light on similar studies among other countries. We provide a model for appliance-service studies and its socioeconomic determinants. We believe that the outcomes observed in China can inform us about how the patterns of appliance-service electricity demand might affect other countries as they go through their transitions in their socioeconomic determinants. This will certainly generate important policy implications to enhance global environment. Of course, China and its history are unique in many ways, and extending the analysis to other places and times must be done carefully.

Methods

Survey data.

We use the household-level micro survey data, the Chinese Residential Energy Consumption Survey (CRECS) conducted by Department of Energy Economics, Renmin University of China. It is up to now the most comprehensive and detailed national wide household energy survey (Zheng and Wei, 2019). There are six rounds of surveys since the year 2012. Here we select the CRECS 2014 for our analysis. The CRECS 2014 was conducted between July and October 2015 over 28 provinces of China to record the situation of household energy consumption in 2014. The map-based sampling technique was adopted to ensure the representativeness. The CRECS 2014 includes three major modules: the household routine and respondents' socioeconomic variables; reported energy consumption data (including electricity usage and others in 2014), and in-depth detailed home appliances ownership information in each household (whether households having surveyed appliances or not). This unique data structure enables us to first determine ownerships of each of eight electrical services for every household and then disaggregate the household-level electricity consumption data to our desired service clusters. A total of 3,864 questionnaires were issued and the 2,408 completed samples were collected at the end. The sample retrieved rate is 62.3%. After taking off outliers in terms of household income and family size, there remains 2,402 observations in total for analysis.

Sample representative.

SI Table 1 presents descriptive statistics of socioeconomic status variables of household, appliance services ownership, and household electricity consumption of the year 2014 for sampled Chinese households. As we can see, 52% of household head are female, with average age around 55, and middle school education level on average. The average family size is 2.93 and average household annual income is around 58.219 thousand Yuan. The average electricity consumption per household in 2014 is 1,572 kWh. All these statistics are comparable to China Statistical Yearbook 2015 (National Bureau of

Statistics of China, 2015), which shows that in 2014, female ratio is 0.49, family size is 2.97, national average household income is 59.90 thousand Yuan, and average electricity consumption per household in 2014 is 1,505 KWh. This confirms the representativeness of the surveyed data.

Classification of electrical services.

There are 12 types of home appliances ownership recorded in CRECS 2014, which covers almost all electricity-consuming devices commonly used in a typical Chinese household. The appliances are categorized based on their service function following three considerations. **First**, multiple appliances serving a common purpose will be classified into one category, although they are concurrently owned by a typical household. For example, electric rice cooker, induction cooker, pressure cooker, and microwave oven will be sorted into Cooking as they all serve cooking purpose. **Second**, one type of electricity appliance may be sorted into two difference service as it can provide different kinds of important services. Take air conditioner for example. It can offer either space cooling service in summer or space heating service in winter. Thus, the two services are distinguished on air conditioner. **Third**, some type of electricity appliance can serve multiple purposes but may be only sorted into one main function. For instance, computer can be used for both work and entertainment. But according to recorded usage habits of respondents, most of the time they use home computer is for entertainment purpose. Thus, the computer is categorized into entertainment service together with the television.

SI Table 2 distinguishes and categories eight types of electrical service based on the appliances' function. For each type of service, the household is marked as having the service if it owns any of the corresponding appliances. Otherwise it is marked as having no such service. There are total 8 services that we would disaggregate household added-up electricity consumption into and explore how each type of service responds to socioeconomic status.

Conditional demand analysis model.

Several methods have been developed to disaggregate household electricity consumption to electrical devices. It includes the engineering method (Carlson et al., 2013; Zheng and Wei, 2019), signal processing technologies (Swan and Ismet Ugursal, 2009; Zeifman and Kurt, 2011; Berges et al., 2011). Although there are some merits of these methods, they suffer expensive costs for data monitor and collection for specific devices. Moreover, it is limited to capture behavioral impacts of household characteristics on residential electricity consumption.

Since it is able to overcome the two drawbacks, the conditional demand analysis (CDA) model has been widely used for residential electricity demand analysis for various developed countries (Larsen and Nesbakken, 2004; Newsham and Donnelly, 2013; Matsumoto, 2016).

The CDA model is used in the paper to decompose the total electricity consumption into various services demand and to simultaneously model the impact of different socioeconomic variables. We first estimate the model using the whole sample and then proceed to do subgroup analysis in urban area vs. rural area.

The electricity consumption x_{ij} of the *i*-th household and *j*-th service can be estimated as follows (Dalen and Larsen, 2015).

$$x_{ij} = \gamma_j + \sum_{m=1}^{M} \rho_{jm}(C_{im} - \overline{C_{jm}}) + \varepsilon_{ij} \tag{1}$$

where γ_j is the average electricity consumption of service j for households possessing service j. C_{im} denotes the mth ($m = 1, 2, ..., M$) socioeconomic characteristic of household i. $\overline{C_{jm}}$ is the mean of the mth socioeconomic characteristic of households having service j. The coefficient ρ_{jm} measures how the deviation of C_{im} from $\overline{C_{jm}}$ affects γ_j. ε_{ij} is a stochastic error term.

Based on the fact that each of service-specific electricity consumption can be added up to obtain household aggregate electricity consumption and by means of introducing a dummy variable D_{ij} that indicates whether households have specific service, the total electricity consumption x_i of household i can be written as:

$$\begin{aligned} x_i &\equiv \sum_{j=CO}^{SH} x_{ij} D_{ij} \\ &= \sum_{j=CO}^{SH} \gamma_j D_{ij} + \sum_{j=CO}^{SH} \sum_{m=1}^{M} \rho_{jm} (C_{im} - \overline{C_{jm}}) D_{ij} + \varepsilon_{ij} D_{ij} \end{aligned} \tag{2}$$

Equation (2) is the specification to be estimated by using ordinary least squares. γ_j and ρ_{jm} are parameters to be estimated. The predicted expected electricity consumption for service k can be calculated as mean electricity consumption for service k multiplied by the proportion of households possessing service k:

$$x_k^P = \hat{\gamma}_k \overline{D_k} \tag{3}$$

The share of electricity consumption for service k is calculated by x_k^P divided by the mean observed electricity consumption for all households in our sample.

$$a_k^P = \frac{x_k^P}{\overline{x}} \tag{4}$$

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Supplementary note

SI Table 1. Descriptive statistics (mean and stand deviation in parentheses).

Variables		Definition (Unit)	China	# urban	# rural	p-value
Socioeconomic variables	Head's gender	male=0 female=1	0.52 (0.50)	0.52 (0.50)	0.53 (0.50)	0.639
	Head's age	years	54.74 (16.07)	56.1 (16.63)	53.8 (15.60)	0.001
	Head's education	schooling years	8.55 (4.55)	10.74 (4.06)	6.99 (4.23)	0.000
	Household income	Yuan	58219 (71920)	79543 (86733)	42879 (54066)	0.000
	Family size	persons	2.93 (1.36)	2.74 (1.23)	3.07 (1.42)	0.000
	Having teenagers	yes=1 no=0	0.29 (0.46)	0.24 (0.43)	0.33 (0.47)	0.000
Appliances services ownership [a]	Entertainment	have=1 do not have=0	0.97 (0.16)	0.99 (0.11)	0.96 (0.19)	0.001
	Fresh keeping		0.85 (0.36)	0.92 (0.27)	0.79 (0.41)	0.000
	Laundry		0.80 (0.40)	0.88 (0.32)	0.74 (0.44)	0.000
	Cooking		0.76 (0.42)	0.82 (0.38)	0.72 (0.45)	0.000
	Lighting [b]		0.55 (0.50)	0.58 (0.49)	0.53 (0.50)	0.007
	Space cooling		0.41 (0.49)	0.61 (0.49)	0.27 (0.44)	0.000
	Hot water		0.37 (0.48)	0.52 (0.50)	0.25 (0.44)	0.000
	Space heating		0.09 (0.28)	0.11 (0.31)	0.07 (0.25)	0.001
Electricity consumption in 2014		KWh	1572 (1325)	1919 (1506)	1323 (1114)	0.000
Sample size			2402	1005	1397	

Note: [a] Services are presented by mean ownership in descending order.

[b] We define lighting points equal to one if the number of lights in one household outweighs 6 and lighting points equal to zero otherwise, similarly hereinafter.

SI Table 2. Electrical appliances and their corresponding services.

Services	Electrical appliances
Cooking	Electric rice cooker, Induction cooker, Pressure cooker, Microwave oven
Entertainment	Television, Computer
Fresh keeping	Refrigerator/Freezer
Hot water	Electric kettle, Electric water heater
Laundry	Washing machine/Dryer
Lighting	Lighting points
Space cooling	Air conditioner (cooling) [a]
Space heating	Air conditioner (heating) [a], Electric heater, Electric oil heater, Electric heating film

Note: [a] The air conditioner can be used for space cooling in summer and for space heating in winter. The two distinct services are distinguished in the study.

SI Table 3. Estimated conditional demand model.

Variables	China			#Urban			#Rural		
	coef	*t*	p-value	coef	*t*	p-value	coef	*t*	p-value
Entertainment	492.094	5.400	0.000	617.560	2.811	0.005	474.028	4.658	0.000
**Gender*	98.762	0.635	0.526	29.715	0.077	0.939	203.942	1.311	0.190
**Age*	-4.763	-0.78	0.436	-0.214	-0.016	0.988	-3.781	-0.588	0.557
**Educational level*	3.338	0.163	0.871	-27.052	-0.512	0.609	6.510	0.285	0.776
**Household income*	-0.003	-1.725	0.085	0.002	0.404	0.686	-0.004	-2.350	0.019
**Family size*	-21.680	-0.374	0.708	-320.422	-2.342	0.019	88.519	1.514	0.130
**Having teenagers*	-37.956	-0.189	0.850	311.819	0.589	0.556	-119.171	-0.607	0.544
Fresh keeping	366.859	3.870	0.000	370.216	1.702	0.089	325.730	3.122	0.002
**Gender*	81.561	0.516	0.606	-53.780	-0.135	0.892	92.987	0.606	0.545
**Age*	-1.184	-0.188	0.851	-11.927	-0.860	0.390	-0.109	-0.017	0.987
**Educational level*	37.414	1.729	0.084	12.139	0.218	0.827	45.142	2.028	0.043
**Household income*	0.001	0.286	0.775	-0.002	-0.380	0.704	-0.001	-0.339	0.734
**Family size*	2.041	0.035	0.972	86.138	0.545	0.586	16.263	0.282	0.778
**Having teenagers*	-212.346	-1.093	0.274	-557.787	-1.039	0.299	-202.374	-1.098	0.272
Laundry	259.153	3.371	0.001	338.288	1.859	0.063	170.191	1.927	0.054
**Gender*	-77.743	-0.560	0.576	-160.096	-0.491	0.623	-67.416	-0.487	0.627
**Age*	-0.018	-0.003	0.998	-0.463	-0.038	0.970	-0.028	-0.005	0.996
**Educational level*	-0.368	-0.020	0.984	4.694	0.101	0.919	-15.734	-0.790	0.430
**Household income*	0.003	2.619	0.009	0.004	1.556	0.120	0.003	2.154	0.031
**Family size*	73.055	1.378	0.168	121.269	0.903	0.367	41.224	0.784	0.433
**Having teenagers*	85.771	0.479	0.632	-3.849	-0.008	0.994	244.523	1.396	0.163
Cooking	97.796	1.645	0.100	20.641	0.147	0.883	131.866	1.681	0.093
**Gender*	83.871	0.698	0.485	256.391	1.087	0.277	-21.437	-0.165	0.869
**Age*	3.748	0.817	0.414	3.455	0.424	0.671	6.033	1.075	0.283
**Educational level*	-0.751	-0.047	0.963	59.386	1.654	0.098	-9.650	-0.505	0.614
**Household income*	0.000	0.435	0.663	-0.003	-1.502	0.134	0.001	0.883	0.377
**Family size*	8.774	0.196	0.845	206.111	2.154	0.031	-75.784	-1.635	0.102
**Having teenagers*	188.412	1.270	0.204	73.633	0.239	0.811	217.942	0.391	0.165
Lighting	257.731	5.005	0.000	225.666	2.008	0.045	354.286	5.076	0.000
**Gender*	-283.601	-2.750	0.006	-136.761	-0.719	0.472	-368.208	-3.168	0.002
**Age*	5.177	1.334	0.182	15.142	2.201	0.028	-0.242	-0.050	0.961
**Educational level*	-1.492	-0.110	0.912	17.172	0.603	0.547	-6.980	-0.415	0.678
**Household income*	0.000	-0.356	0.722	-0.002	-1.894	0.059	0.003	2.175	0.030
**Family size*	84.245	2.072	0.038	183.345	2.227	0.026	41.848	0.972	0.331
**Having teenagers*	-33.876	-0.270	0.787	96.998	0.407	0.684	-161.945	-1.165	0.244
Space cooling	474.761	7.550	0.000	500.062	4.585	0.000	309.708	3.194	0.001
**Gender*	-73.225	-0.666	0.505	108.397	0.544	0.586	-239.215	-1.778	0.076
**Age*	1.077	0.258	0.796	3.303	0.453	0.651	-12.111	-2.078	0.038
**Educational level*	-1.288	-0.086	0.931	-16.684	-0.566	0.572	-30.668	-1.543	0.123

**Household income*	-0.002	-1.666	0.096	-0.001	-0.984	0.326	0.000	-0.318	0.751
**Family size*	176.998	4.189	0.000	265.385	3.205	0.001	56.088	1.168	0.243
**Having teenagers*	-68.367	-0.513	0.608	-73.424	-0.289	0.772	56.986	0.360	0.719
Hot water	376.816	6.786	0.000	343.999	3.490	0.001	310.971	3.495	0.000
**Gender*	-27.841	-0.259	0.796	-56.331	-0.306	0.760	-74.393	-0.561	0.575
**Age*	2.776	0.703	0.482	3.992	0.607	0.544	-3.641	-0.635	0.526
**Educational level*	-35.595	-2.464	0.014	-48.176	-1.718	0.086	-35.341	-1.803	0.072
**Household income*	0.003	3.443	0.001	0.004	3.149	0.002	0.003	1.839	0.066
**Family size*	-37.480	-0.886	0.376	-54.069	-0.686	0.493	-68.498	-1.411	0.159
**Having teenagers*	275.795	2.138	0.033	140.261	0.604	0.546	457.069	2.970	0.003
Space heating	194.198	2.211	0.027	228.191	1.335	0.182	254.664	1.785	0.075
**Gender*	216.499	1.215	0.224	166.199	0.573	0.567	359.988	1.616	0.106
**Age*	11.335	1.706	0.088	12.059	1.110	0.267	15.329	1.460	0.145
**Educational level*	53.324	2.086	0.037	27.461	0.535	0.593	78.432	2.216	0.027
**Household income*	0.001	1.245	0.213	0.003	1.795	0.073	-0.001	-0.636	0.525
**Family size*	106.477	1.407	0.159	217.419	1.679	0.093	-8.680	-0.096	0.924
**Having teenagers*	17.196	0.083	0.934	-45.111	-0.126	0.899	122.831	0.477	0.634
R^2		0.673			0.683			0.674	
F-statistic		89.289***			39.660***			52.491***	

SI Table 4. Average electricity consumption of each service.

Service types		(1) estimated coefficients	(2) ownership	(3)=(1)*(2) average electricity consumption (kWh)	(4) percent (%)
China	*Entertainment*	492.094	0.97	477	30.36
	Fresh keeping	366.859	0.85	312	19.83
	Laundry	259.153	0.80	207	13.19
	Cooking	97.796	0.76	74	4.73
	Lighting	257.731	0.55	142	9.02
	Space cooling	474.761	0.41	195	12.38
	Hot water	376.816	0.37	139	8.87
	Space heating	194.198	0.09	17	1.11
Urban	*Entertainment*	617.560	0.99	611	31.86
	Fresh keeping	370.216	0.92	341	17.75
	Laundry	338.288	0.88	298	15.51
	Cooking	20.641	0.82	17	0.88
	Lighting	225.666	0.58	131	6.82
	Space cooling	500.062	0.61	305	15.90
	Hot water	343.999	0.52	179	9.32
	Space heating	228.191	0.11	25	1.31
Rural	*Entertainment*	474.028	0.96	455	34.40
	Fresh keeping	325.730	0.79	257	19.45
	Laundry	170.191	0.74	126	9.52
	Cooking	131.866	0.72	95	7.18
	Lighting	354.286	0.53	188	14.19
	Space cooling	309.708	0.27	84	6.32
	Hot water	310.971	0.25	78	5.88
	Space heating	254.664	0.07	18	1.35