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Working Paper 109
http://ceep.bit.edu.cn/english/publications/wp/index.htm

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January 2018

This paper can be cited as: *Hou, B.D., Tang, X., Ma, C., Liu, L., Wei, Y.M. and Liao, H., 2018. Cooking fuel choice in rural China: results from microdata.. CEEP-BIT Working Paper.*

We sincerely thank the financial supports from the "Strategic Priority Research Program" of the Chinese Academy of Sciences (No. XDA05150600), National Natural Science Foundation of China (No. 71322306, 71273027, and 71521002), Program for New Century Excellent Talents in University of Ministry of Education of China (No. NCET-13-0040), Program for Excellent Young Talents in Universities of Beijing (No. YETP1181), the Australian Research Council for funding (DP120101088), and the University of Western Australia (Research Collaboration Award). The views expressed in this paper are solely authors' own and do not necessarily reflect the views of the supporting agencies and author affiliations. The authors alone are responsible for any remaining deficiencies.

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Residential fuel choice in the rural: A field research on two counties of North China

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Abstract: Solid fuels are still widely used in rural China though the living standard has improved greatly. Energy poverty is an obvious indicator of poverty, which has serious effect on economic development, environment and health. In this paper, we conducted a detailed analysis on fuel choice and usage behavior of different end-use activities in rural residential energy consumption. Using 717 household observations from a micro survey data in two counties of Shandong and Hebei province in 2016, we find that biomass is the dominant fuel used for cooking among all energy sources despite of obvious trend of decrease in recent years, accounting for 44%. Clean energy used to cook increased markedly with a proportion of nearly 50%. Biomass is also the ordinary fuel used for water heating excerpt for solar energy. Almost 90% households rely on coal for space heating in winter, and one-third households have space heating less than 2 months. Ownerships of home appliances for basic needs is higher than that for hedonistic needs, and usage behaviors of some appliances are economical. Fuel accessibility of commercial energy has improved noticeably in rural, and the high proportion usage of biomass is affected by family income, using habits, local resources, environmental recognition, education and age. Since solid fuels are widely used in rural, it is important to cleanse biomass, develop new energy, and improve residents' cognition about the consequences of using solid fuels.

Keywords: rural households; fuel choice; end-use; usage behaviors

1. Introduction

With the progress of industrialization and urbanization, China's rapidly increasing use of energy has received much attention in recent years, and contributed to 28% of global carbon emission in 2014 [1]. Under the pressure of global warming, Chinese government has positively taken multifaceted actions to reduce carbon emission, which includes the commitment to reduce carbon emission by 40% to 45% in 2020 compared to 2005 and make carbon emission reach to the peak at around 2030, signing the Paris Agreement in 2016. It is necessary to identify the characteristics of different energy consumption sectors before making policies. Though industry sector is the major energy consumer over the last three decades, residential energy consumption has grown rapidly along with the increasing income, accounting for 20% in 2014[2]. The overall people's living standard has improved greatly aside with the development of China's economy. But there is still a huge gap between urban and rural energy consumption, including energy consumption quantity, energy structure, end-use devices and using patterns [3-5]. In rural, energy poverty is an important problem that needed to be solved urgently due to its adverse effects on human health and environment [6], particularly in developing countries [7-10].

China has a great population, and 44% population living in rural in 2015[11], who have been suffering great harm from the use of solid fuels (mainly biomass and coal) [12, 13]. Since early 1980s, Chinese government has invested plenty of resources to improve the efficiency and to cleanse rural energy structure, such as the construction of biogas, the implementation of mini-hydropower plants,

the development and diffusion of biomass gasification stations. The most notable effort is the National Improved Stove Program (NISP), this program promised to offer rural households more efficient biomass stoves, which is beneficial to environment and human health. Though those programs have made great achievements in improving the level of rural energy consumption, difficulties still exist and constraint the development of these programs [14-16].

There are many researches related to rural energy consumption, including energy consumption structure, energy poverty, characteristics of energy usage, air pollution and health impacts, construction of new energy, especially focusing on developing countries [17-19]. In China, extensive researches on rural energy consumption have been conducted in several aspects. One branch of them is engaged to describe characteristics of rural energy consumption on regional differences, changing of energy structure, energy consumption of end-use, affecting factors over the country or key provinces and regions [20-22]. Several researches focus on cooking fuel choice based on micro survey data due to its high percentage of total energy consumption [23-25]. The development of constructing new energy and cleansing biomass is also an important approach to improve the energy structure and living standard of rural households, and several papers discussed the opportunity, constrains, implications of clean energy[26-28]. Besides, the analysis of health effect, well-being, economic and environmental cost resulted from carbon emission and indoor air pollution that induced by solid fuels combustion are of great concern to researchers [29-32]. This paper is closely related to describe the characteristics of rural energy consumption, and there are many researches focus on it, and they focus on the energy consumed and energy structure, energy end-use activities, provide a profile of rural energy consumption [33-35]. This paper contributes to describe the characteristics of rural energy consumption and detailed usage behaviors by remedying the data limitation of previous researches through detailed questionnaire design, offering in-depth reasons related to different fuel choice of end-use activities, which can provide some intuitions for decision making.

The rest of this paper is organized as follows, Section 2 describes the field survey design and the descriptive analysis of the data used in this paper. Section 3 presents the different fuel choice and usage behaviors in different end-use activities. Section 4 explores the factors affecting fuel choice of rural residents. Section 5 gives this paper's conclusions and some implications to the government.

2. Field Survey Design and Descriptive Analysis

2.1. Field Survey Design

Conducting residential energy consumption researches rely on large-scale data, especially the micro survey data at household level. In other countries, particularly in developed countries, government agencies regularly collect data on energy-related characteristics and usage patterns of nationally representative samples of households, offering strong support for decision making. For example, the US Energy Information Administration started to survey US households' energy usage in 1978, based on which abundantly informative studies have been conducted. However, few surveys have been conducted nationally and periodically on residential energy consumption in China. Some researchers conduct micro surveys on specific contents in some areas, which plays an important role in analyzing residential energy consumption.

The data used in this paper is from a field survey that was organized by the Center for Energy & Environment Policy Research of Beijing Institute of Technology. It was conducted on July and August in 2016 in order to collect detailed information about energy use in rural. The questionnaire was designed with comprehensive and detailed questions related to daily energy consumption, including household demographic, dwelling characteristics, kitchen appliances, number and use of energy-consuming products, energy choice of different end-use activities, consumption of different fuels, residents' health and recognition to environment.

Multistage cluster sampling method was used in this field survey. First, we chose Qihe County in Shandong Province and Wuqiang County in Hebei Province. Both of the provinces are located in North China. Then townships were randomly drawn from Qihe and Wuqiang county. Villages were chosen finally, and villages in this survey are defined with a code of "220" according to the Region and Urban/Rural Classification of National Bureau of Statistics of China, which refer to a village that

less-developed. The final sample is all of the households living in primary residence for over half year of each selected village, and confirmed by register-base population information, excluding households that have long-term works outside, or transferred. Under the support of local village committee, a family member, householder or his wife usually, who is knowledgeable about energy use in each household was required to join this survey in local committee. The interview took 30 minutes per household on average. Finally, 730 households were surveyed and 717 samples were eligible, with a high response rate of 98%. Besides, we also collected 1924 personal information of people living in home over six months in a year, but the family member who is working outside for a long time or boarding at school was not in our consideration. In this field survey, measures of quality assurance were implemented at each step of data collection, including extensive training of interviewers about the survey procedures and questionnaire, picture assistance, data validity and consistency checks.

2.2. Descriptive Analysis

Qihe county is located in the northwest of Shandong province, which is close to the provincial capital Jinan. The total area of Qihe is 1411 square kilometers, and with a total population of 0.78 million. Qihe lies in the north bank of the lower reaches of Yellow River, and it is an important food production area of Shandong. The forest coverage is approach to 47%. Qihe county has rapid growth of economy due to its abundant resources, advantaged location, developed traffic, and it is one of the National Hundred Strong Counties in China. Wuqiang county is located in the southeast of Hebei province, the total area is 445 square kilometers, total population is 0.219 million. It is a key county in the national plan for poverty alleviation through development work. As the Figure 1 shows, both of them are parts of North China Plain, located in the temperate monsoon region. The cumulative annual average temperature of Qihe and Wuqiang is 13.7 °C and 12.8 °C respectively, and cumulative daily mean temperature of Qihe is 2 °C below zero, and Wuqiang is 4 °C below zero.

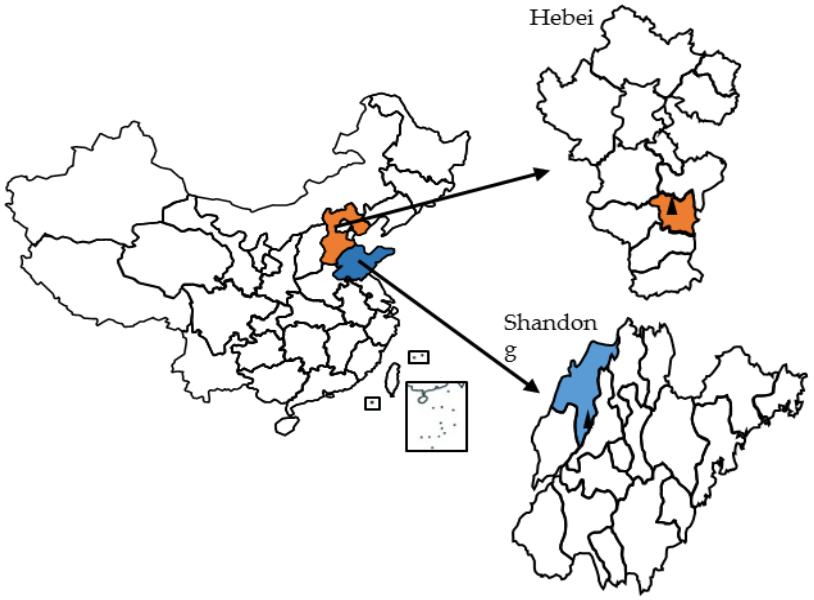


Figure 1. The location of Qihe and Wuqiang
Notes: the figure of triangle represents the location of the county surveyed

A descriptive statistics of household social-economic characteristics has been presented in Table 1. In our survey, Qihe county has a sample of 391 observations from six different villages, and Wuqiang county has 326 observations from four villages. On average, 3.55 people registered in permanent residence booklet per household, while only 2.54 people eat together every day. Family members working outside or living in dormitory have been excluded in our survey, and it has slightly difference between two counties. Male percentage and average age in our survey of Wuqiang county is lower than that of Qihe county as the higher household members working outside, and people working outside is usually male in Wuqiang. The average schooling years of the householder is below 6 years, which is just an education level of primary school, and Wuqiang county is higher than Qihe county.

The average annual income of the surveyed households is 21223 Yuan, and the median is 13644 Yuan, which indicates the gap between the rich and the poor. Besides, households of Qihe county have a higher average income than that of Wuqiang county because of its better economic development level. The percentage of households that have one or more family members working outside over six months in Qihe county is higher than Wuqiang county. Most of household members rely on agriculture for living in the two counties, which is accounting for 73% in total, and some families have a part-time work in slack farming seasons.

Table 1. Descriptive statistics of household characteristics.

Varable	Total	Qihe	Wuqiang
Number of observations	717	391	326
Male percentage (%)	48.8	50	47
Household size of Hukou	3.55	3.6	3.5
Household size of eating together	2.54	2.45	2.64
Average age	46.8	47.7	45.9
Schooling years of householder (year)	5.4	5.1	5.7
Average household income (Yuan)	21223	23130	18968
Median of household income (Yuan)	13644	15000	11520
Farmer percentage (%)	73	71	76
Family members working outside (%)	47	52.4	40.5

Notes: Household size of *Hukou* stands for people registered in permanent residence booklet on average, while household size of eating together stands for family members most of time living and eating together. Farmer percentage stands for the percentage of family members relying on agriculture for living. Family members working outside are defined as the percentage of households that have one or more family members working outside over six months in a year.

In this survey, dwellings of the same village are usually designed and constructed uniformly, including area size, structure, construction materials and floor height. Most households own one dwelling with one story, only 12% households have two dwellings, and 95% dwellings are self-built. More than half of the dwellings were built before 2000, and most of them serve life less than 20 years. Total area and net area of per household is 288 m^2 and 92m^2. The net area of per capita in Qihe and Wuqiang is 39m^2 and 26m^2.

As this survey is engaged to describe household energy consumption for daily life, we just collected demographic information of people living in primary residence over six months, thus is the group of the left-behind, who have direct connection to energy consumption. We make a comparative analysis of age structure between this survey and the National Bureau of Statistics (NBS) to demonstrate the characteristics of people who are left-behind in Figure 2. Firstly, people aged over 65 years in our survey accounting for 23%, more than twice higher than that of NBS statistic (10%); on the other hand, labor force population is smaller in our survey for people working outside. Secondly, percentage of people under 14 years in our survey is smaller for some children live with their parents who are working outside, or live in a boarding school. Thirdly, age of the left-behind concentrates in the range of 50-70, accounting for 43% of the total as Figure 3 presents. Because the majority of the left behind are the elderly or children, it is difficult to acquire an accurate amount of fuel consumption due to their limited recognition[35], thus we use primary fuel choice to substitute quantity for different end-use fuels.

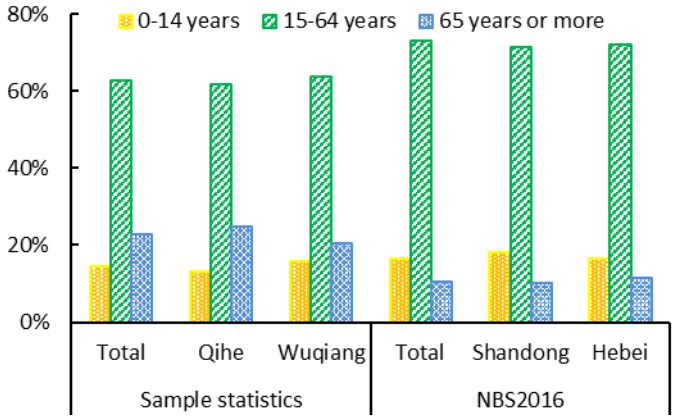


Figure 2. Comparative analysis of age structure between this survey and NBS statistics

Notes: Data source is from our survey and China Statistical Yearbook 2016 (1% Population Sample Survey in 2015), and age structure is classified according to the NBS classification. The sample statistics presents the age structure of the left-behind in total (two counties together), Qihe and Wuqiang, and the NBS stands for the age structure of the whole population of the country, Shandong and Hebei province.

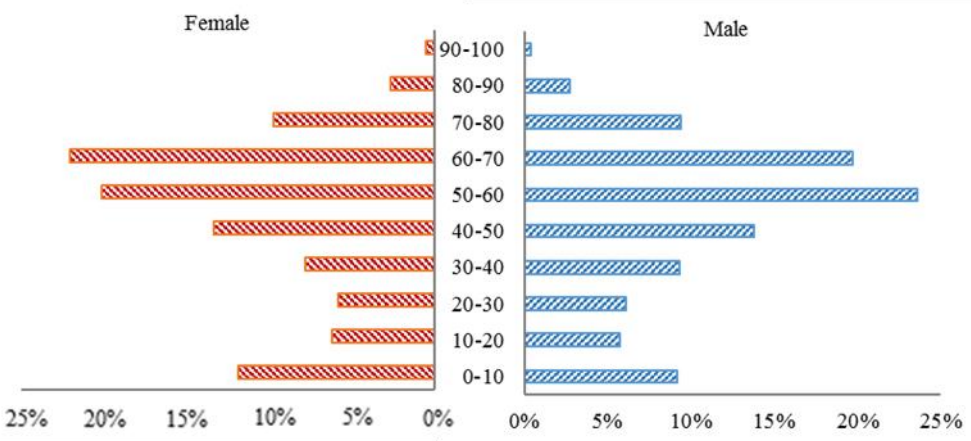


Figure 3. The age structure of the left-behind

Notes: This figure describes the detailed age structure of the left-behind by gender based on our survey data.

3. Fuel Choice and Usage Behavior of Different End-use

3.1. Cooking Stoves

In rural, there are several types of cooking stoves for different fuels, including traditional stove with biomass(mainly wood and crop residue), coal stove (including inferior and advanced, a coal stove without chimney is defined as inferior coal stoves, thus the advanced coal stove is equipped with chimney.), LPG stove, electric stove. Many households use different stoves in different time and situation. Figure 4 provides sample statistics on household stoves use, we find that traditional stove is widely used in rural, accounting for 79%, which is mainly used for staple food, such as steaming bread with a frequency of three times a month, or making porridge every day. The second commonly used stove is LPG stove, accounting for 68%. Many households use it for sautéing dishes once a day or twice a day. There are 45% households using electric stove for cooking, which can be used to cook dishes, and 74% households own electric rice cooker. In addition, about 15% households use inferior coal stove and 11% use advanced coal stove to cook, usually in winter. Inferior coal stove with poor ventilation can lead to serious impact on indoor air quality when use it to cook or heat space.

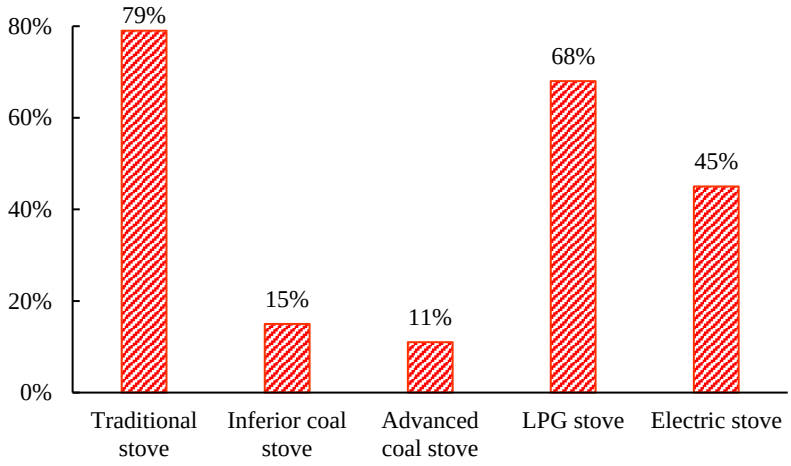


Figure 4. Percentage of cooking stove types of per 100 households

Notes: Traditional stove is defined as hand-made brick stove, coal stove without chimney is defined as inferior coal stove, thus advanced coal stove is equipped with chimney, LPG stove mainly consume LPG, electric stove is defined as stove can cook dishes by consuming electricity.

3.2. Cooking Fuel Choice of Current Situation

Cooking activity is a main component of people's daily life, this activity usually consumes plenty of energy. According to other's research, percentage of energy used to cook takes as high as 43% of total energy used in rural, which is far beyond that in the urban of China and the developed countries [33]. Figure 5 presents the proportion of different cooking fuel choice in 2016, we can see that rural residents use diversified fuels for cooking, including firewood, straw, coal, LPG, electricity, etc. As for primary cooking fuel, about 14% and 30% households choose firewood and straw, straw is more widely used in rural. Only 5% households choose coal, and households use LPG and electricity hold 13% and 35% respectively. Biomass is the dominant fuel choice for cooking among all energy sources, which is consistent with others' research [23]. There exist some differences between the two counties, more households choose firewood and LPG as primary cooking fuel in Qihe, while more households take straw and electricity in Wuqiang, and lesser households choose coal as cooking fuel.

When it refers to the secondary cooking fuel, the five types of fuels accounting for 9%,20%,6%,44% and 19% respectively. Making a comparison between primary and secondary cooking fuel choice, it is obvious that more households choose biomass, electricity as primary cooking fuel, while LPG is usually taken as secondary cooking fuel. It indicates to some extent households have different using preferences for different fuels when other fuels are available.

More specifically, nearly half households choose solid fuels (mainly biomass and coal) as primary cooking fuel, the rest choose clean fuels (mainly LPG and electricity). Compared to primary cooking fuel choice, more households choose clean fuels as secondary cooking fuel, close to 63%, and Wuqiang is higher than Qihe. In rural, it is common to use a combination of fuels rather than use a single fuel to cook, when households choose solid fuels as primary cooking fuel, the percentage of they choose solid fuels as secondary cooking fuel is 18% while clean fuels accounting for 30%, clean fuels are usually used as subsidiary fuel in those families. When households choose clean fuels as primary cooking fuel, they also more prefer to use clean fuels as secondary cooking fuel, which is accounting for 34%. The combination of solid fuels and clean fuels is widely used to cook in rural, accounting for 48%, fuel stacking still widely exists in rural [36].

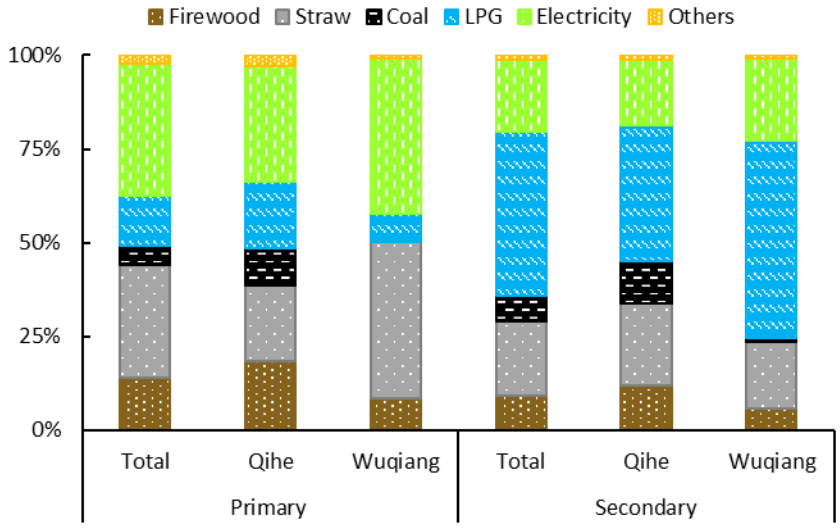


Figure 5. Percentage of primary and secondary cooking fuel choice

Notes: Vertical axis represents the percentage of different fuels used to cook, horizontal axis represents fuel structure of primary and secondary cooking fuel choice in total, Qihe and Wuqiang.

3.3. Changes of Cooking Fuel Choice

Figure 6 describes the trend of different cooking fuels in 2006, 2011 and 2016, which indicates that the percentage of households using solid fuels decreased, and clean fuels increased regardless of primary and secondary choices in recent 10 years. This trend is closely connected to the development of China economy lead to the improvement of personal income and living standard. More specifically, though firewood and straw has decreased by 40% and 43% respectively in recent 10 years, they still have a large share (44%) in 2016, which is consistent with common results that biomass still the main fuel choice to cook in rural[30]. On the contrary, the percentage of clean fuels is just less than 50% despite LPG and electricity each largely increased by more than one times and three times in primary cooking fuel. In conclusion, the cooking fuel transition follows the general rule, changing from traditional energy to modern energy[22, 37].

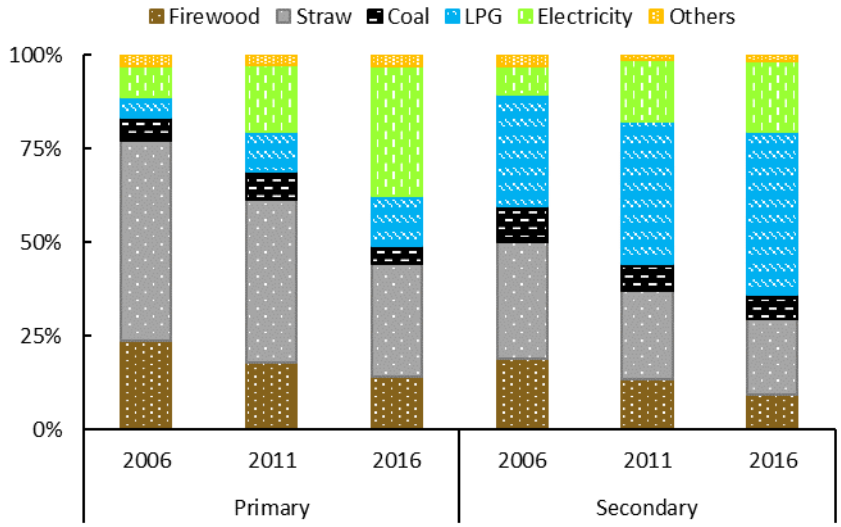


Figure 6. Changes of primary and secondary cooking fuel choice in recent 10 years

Notes: Vertical axis represents the percentage of different fuels used to cook, horizontal axis represents fuel structure of primary and secondary in 2006, 2011, 2016.

3.4. Water Heating

Water heating service includes drinking water, bathing, washing clothes and tableware, and this is a basic need for daily life. In this study, we analyze fuel choice of hot drinking water and bathing. Figure 7 shows that almost 65% households use biomass to boil drinking water, the second fuel used is electricity, accounting for 25%, the rest fuels just hold a small percentage. It is more efficient and convenient to use electricity to boil water than biomass according to our knowledge, but the percentage of using biomass is greater than electricity. We find that households usually use a commercial firewood stove to boil water for basic need universally, they tend to place it outdoor and use it frequently. Besides, percentage of electricity used to boil drinking water is higher in Wuqiang than that of Qihe, and the coal usage is lesser, which may be caused by different policy restrictions.

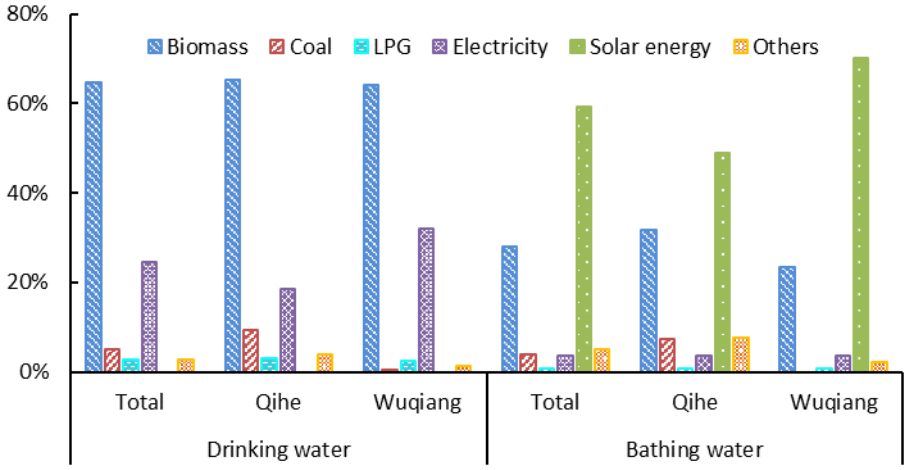


Figure 7. Primary fuel choice of drinking water and bathing

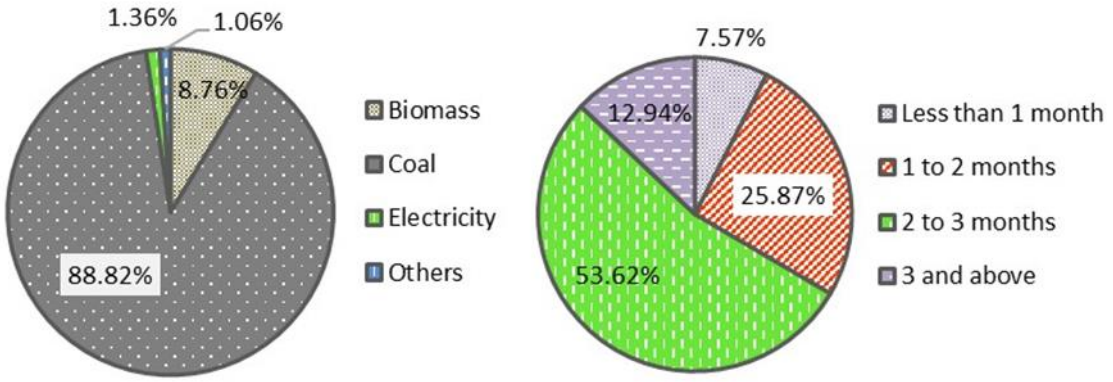
Note: Vertical axis represents the percentage of primary fuels used for water heating, horizontal axis represents drinking water and bathing water in total, Qihe and Wuqiang. No household use solar energy to boil drinking water, and no household use coal to boil bathing water in Wuqiang, so the percentage is zero.

Unlike hot drinking water, households usually use solar energy for bathing, which is accounting for 59%, the second frequently used fuel is biomass, accounting for 28%. Furthermore, solar energy is more widely used in Wuqiang, because the ownership of solar water heater per 100 households is 36% and 44% in Qihe and Wuqiang, respectively. We find that many households use an iron-bucket to absorb solar energy for their bathing need in Wuqiang, which is convenient and inexpensive.

3.5. Space Heating and Cooling

Qihe and Wuqiang is located in the north of China, the temperature is low in winter, thus there is a great demand for space heating. Though Chinese government began to provide a centralized heating system in 1958, the policy just focused on city-wide centralized heating to northern cities only [38]. In rural, people take measures to keep warm by themselves. In our survey, more than 92% households use different devices for their space heating demand, including coal stove, traditional Kang, electric heating fan, and air conditioning, while the rest haven't space heating. Coal stove is the most common device which mainly combust coal, amounting to as much as 89% as shown in Figure 8(a). 9% households combust biomass in Kang to heat their bed, and households hardly use electricity for space heating even they own air conditionings. Generally, space heating device is commonly used from November to March. In our survey, Figure 8(b) shows about 26% households use it for two months, 53% for three months and only 13% use it for more than 3 months in Wuqiang county, which is a frugal consumption.

Air conditioning is the most common appliance for space cooling in urban, while electric fan is more widely used in rural for its cheap price. In our survey, more than 70% households use electric fan for space cooling, 6% households use air conditioning, and the rest don't have space cooling.



(a)Fuel choice (b)Usage time

Figure 8. Fuel choice and usage time of space heating

Notes: The left pie chart stands for fuel choice of space heating in winter, and the right pie chart stands for the months of households have space heating.

3.6. Appliances

With the improvement of rural living standard, usage of home appliances become universal, and ownerships of appliances can reflect household wealth and electricity consumption. In our survey, refrigerator, television, washing machine are common in rural households, ownerships of such appliances per 100 households accounting for74%, 105%, 69% respectively. While ownerships of air conditioning, microwave, exhaust fan and computer are low, just accounting for 33%, 3%, 10%, 20% respectively. We find that appliances for basic need are used universally in rural, but possession rates of other appliances for hedonistic needs are low, just owned by wealthier households.

Figure 9 and Figure 10 shows the ownerships of different appliances per 100 rural households in Qihe and Wuqiang. In Qihe county, ownership of refrigerator, television, computer is higher than that of Wuqiang, while Wuqiang has higher percentage of exhaust fan, washing machine, air conditioning, which is consistent with the data published by NBS. In our survey, ownerships of appliances are lower than that of NBS, especially in microwave, exhaust fan, air conditioning and computer, which is because our survey focus on less developed villages while the NBS' data stands for the whole province.

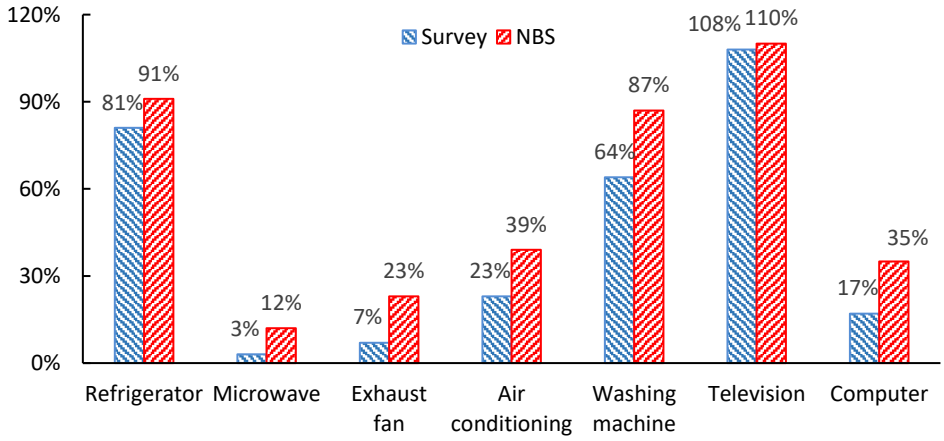


Figure 9. Ownerships of different appliances per 100 rural households in Qihe

Notes: Ownerships of appliances in our survey stand for the sample statistics of Qihe in 2016, and NBS statistics stand for the rural households of Shandong province in 2015. Data source of the NBS is from the China Statistical Yearbook 2016.

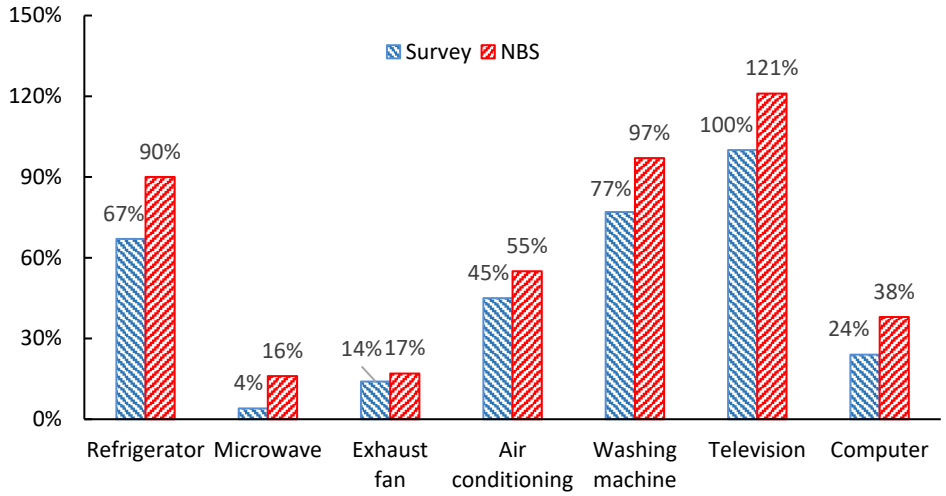
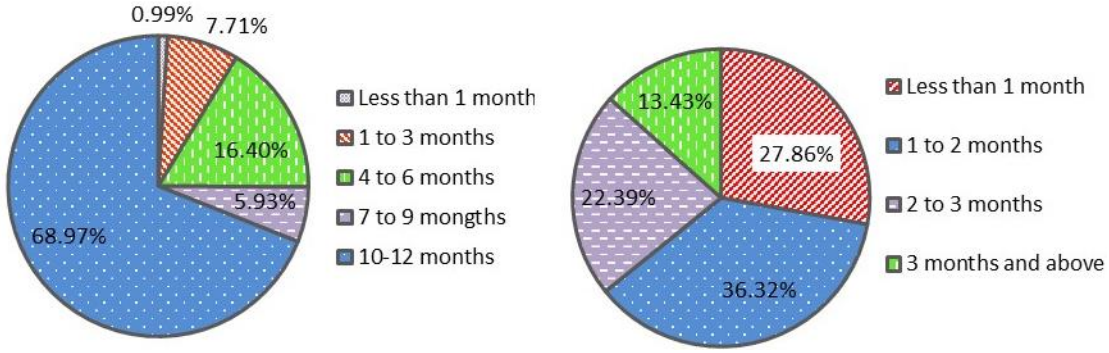


Figure 10. Ownerships of different appliance per 100 households in Wuqiang

Notes: Ownerships of appliances in our survey stand for the sample statistics of Wuqiang in 2016, and NBS statistics stand for the rural households of Hebei province in 2015. Data source of the NBS is from the China Statistical Yearbook 2016.

Energy efficiency label is proved to be a powerful program to reduce energy consumption in developed countries [39,40]. In this survey, types of refrigerator and air conditioning of households purchased was included, and the percentage of refrigerator and air conditioning that is energy-efficient accounting for 60% and 63% respectively, while about 10% households know little about energy efficiency. We can find that China's energy efficiency program has a wide cognition in recent years, but there is still space to improve.

This survey also questioned households about the duration of the use of refrigerator and air conditioning, the usage behaviors of such appliances are presented in Figure 11. More than 68% households keep refrigerator on above 10 months, and 66% households keep turning on all year. While the rest households just use it for several months, even 25% households use it for half year or below. The percentage of households using air conditioning is also economical, about 28% households use it less than 1 month, only 13% households use it for 3 months or above in summer, and almost 87% households don't use air conditioning in winter. Furthermore, they just turn it on for several hours in the hottest time of a day.



(a) Refrigerator (b) Air conditioning

Figure 11. Usage time of refrigerator and air conditioning in a year

Notes: Different colors in two pie charts stand for the months of turning refrigerator and air conditioning on respectively.

4. Factors Influence Fuel Choice

4.1. Fuel Accessibility

Fuel accessibility is a major restriction of household energy consumption in less developed regions. Nowadays, commercial fuels are popular in rural of China because of the economic development, and energy poverty in China has relieved markedly [41]. Except natural gas that is widely used in urban due to the professional pipeline facility, coal (including honeycomb briquette) and LPG can be delivered door to door, and most of the deliveries are free. Beside, price of such fuel reduced greatly in recent years, and commercial fuels become convenient and affordable to most households.

Percentage of fuels choice for any use per 100 households are shown in Figure 12, which can reflect the availability of different fuels and affordability of households. It reflects that electricity is the most prevalent fuel in rural. Every household can afford electricity, which is benefited from the wide coverage, cheap price, multiple usage, safety and cleanness of electricity. Firewood and straw are also used universally with high percentage of 78% and 89% respectively. It is well known that biomass(mainly wood and crop residue) is free in rural, and can be collected easily. Straw is more widely used than firewood for straw is a residue of farm corps, thus it can be collected directly and easily. Percentage of coal households choose for any use takes 84%, and mainly used for space heating. LPG also has a high percentage of 73%, many households use it to cook dishes for its more efficient and clean. What's more, the use of solar energy is lower than other fuels, just accounting for 58%, because it needs large cost of purchasing equipment rather than operating.

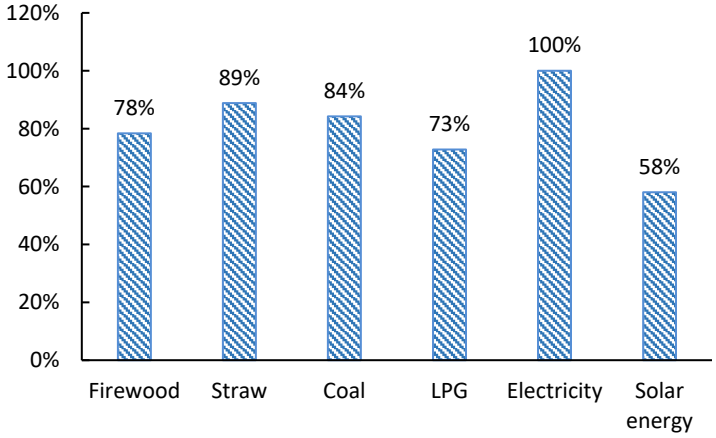


Figure 12. Fuel used for any use per 100 households

Notes: Vertical axis represents the percentage of whether a households use a fuel for any use in their daily life, horizontal axis represents different fuels.

4.2. Income Constraints

Though clean fuels are available in rural nowadays, the use of biomass still takes a large proportion, which means not only considering the availability of fuels, income is also an important factor that influences households fuel choice. For example, Figure 13 presents the relationship between primary cooking fuel choice and income, we find that percentage of households choosing biomass as primary cooking fuel declines when income increases, and clean energy (mainly LPG and electricity) on the opposite, while the percentage of using coal changes slightly. It is consistent with others' research that income is the primary factor affects fuel choice [42,43].

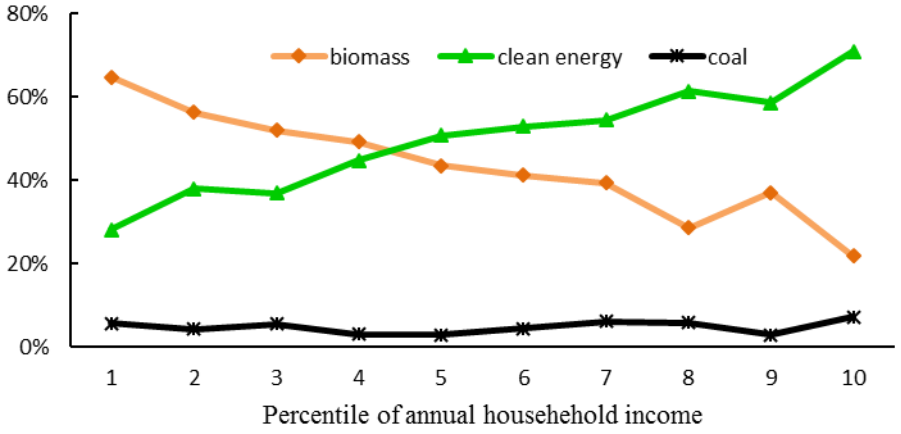


Figure 13. The relationship between primary cooking fuel choice and income

Notes: Vertical axis represents the percentage of households choose biomass(mainly wood and crop residue), clean energy(mainly LPG and electricity), coal as primary cooking fuel respectively, horizontal axis represents the ten percentiles of annual household income.

However, some households still choose biomass as primary cooking fuel even at the group of high income, which is closely related to their using habits. In this survey, when households are questioned which fuels used to cook with good taste, more than 60% households choose biomass. Using biomass to cook isn't time-consuming, it is faster than ever before. So they prefer to choose biomass for cooking or heating water when other fuel is available. And we find that if households choose firewood or straw as primary cooking fuel, most of them use it for several decades, accounting for 87% and 94%, which has formed a habit.

4.3. Limited Recognition

People's recognition of air pollution also plays an important role affecting fuel choice. Though many people know air pollution, about 71% interviewees do not know the differences between outdoor air pollution and indoor air pollution. In addition, almost 78% people know little about the reasons of indoor air pollution, nearly 36% interviewees think that combustion of solid fuels(mainly biomass and coal) have little influence on indoor air quality, and they don't agree that indoor air pollution can harm their health.

Education level and age is the major factor that influence recognition, and it has a great impact on residents' fuel choice [23,42]. The average age of householder is 58 in this survey, which indicates that many elderly people live in rural, and they usually have limited knowledge and educational level. Figure 14 explores the relationship between primary cooking fuel choice and the age of householders. When the householder is older, percentage of the households choose solid fuels as primary cooking fuel is higher. When householders locate at the age between 60 and 80, percentage of they choose solid fuels as primary cooking fuel accounting for 61%, and their average schooling years are 5 years. While householders locate at the age between 20 to 40 accounting for 22%, and their average schooling years are 8 years.

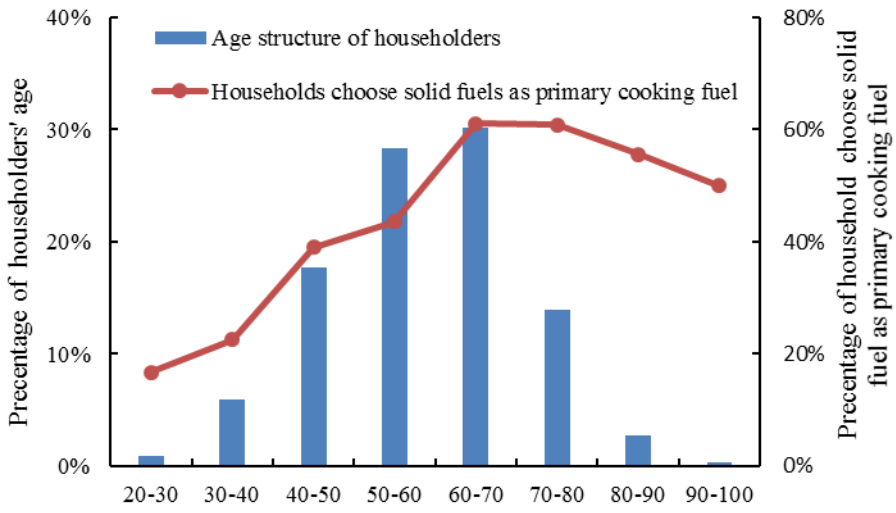


Figure 14. The relationship between primary cooking fuel choice and age structure

Notes: Left vertical axis represents the percentage of householders' age, right vertical axis represents the percentage of households rely on solid fuels(mainly biomass and coal) for cooking, horizontal axis represents different age categories of householders.

5. Conclusions and Implications

This paper presents a descriptive analysis on rural energy consumption based on 717 observations survey in two counties of northern China, and we use primary fuel choice to substitute quantity for different end-use activities due to the left-behind in rural are usually the elderly and children, who have limited recognition about energy consumed. We find that biomass(mainly wood and crop residue) is still the dominant fuel choice for cooking among coal, LPG, electricity and others, accounting for 44%, and straw is more widely used than firewood in rural. Rural residents use diversified energy to cook, and they prefer to use a combination of fuels other than a single one. Furthermore, nearly half households choose solid fuels(mainly biomass and coal) as primary cooking fuel, the rest use clean fuels (mainly LPG and electricity) to cook, and the percentage of using clean energy is larger in secondary cooking fuel choice, which indicates that clean energy is more used for auxiliary energy source. In addition, transition of cooking fuel choice follows the general rules that changes from traditional energy to modern energy. Secondly, biomass is also the common fuel used for water heating, and solar energy is widely used for bathing. Thirdly, coal is the most common fuel for space heating, nearly accounting for 90%, and even one-third households have space heating less than 2 months. Fourthly, the ownerships of home appliances increased largely in recent years, and refrigerators, televisions, washing machine are commonly used in rural, while ownerships of air conditioning, microwave, exhaust fan, computer is much lower, and usage behaviors of some appliances are economical

There are many factors influencing fuel choice in rural, including fuel accessibility, fuel price, income and education. Nowadays, fuel accessibility has greatly increased in rural in recent years, and households use coal, LPG, electricity, solar energy for any use accounting for 84%, 73%,100%, 58%. Though clean fuels can access conveniently, nearly 50% households still choose solid fuels as primary cooking fuel, which is restricted by income to a great extent. Furthermore, using habits and environment recognition, age structure, education level also has influence on it.

Solid fuels are still widely used in rural, biomass is mainly for cooking, coal is the primary fuel for space heating, which have serious damage on environment and health. The high percentage of biomass used to cook is related to several factors including: i) income restriction, and biomass is free, ii) collection of biomass is no longer a time-consuming business, straw is just a residue of agriculture crop, iii) device used to combust biomass is widely self-built in rural, iv) rural residents tend to consume thriftily, v) using habit, many households use biomass to cook for decades, and meals cooked with

biomass have better tastes. vi) the elderly tends to use biomass to cook for their limited income and education.

It is urgent to transfer energy structure in rural, and multiple actions can be taken. Firstly, solid fuels are widely used in rural, and this trend will not change greatly in a short-term due to its accessibility, affordability, convenience and habituation. Therefore, it is necessary to make biomass clean in some food production areas, the opportunity and potential of transforming the use of biomass have enhanced greatly with the improved technology and increased financial support, such as biogas, liquid biofuels, biomass gasification [44-46]. Second, taking the advantage of new energy, especially the solar energy. We find that the initial purchase cost impedes households to use solar energy more frequently and efficiently, government can provide some subsidy for households to install the solar energy device. Third, we find residents have limited knowledge about air pollution and its' related health effects, government can disseminate the source of indoor air pollution, and improve residents' recognition about the damage of combusting solid fuels by figures and videos in consideration of their limited educational level. Guide them to reduce the usage of biomass, and open window or keep good ventilation when use it. Besides, we find that fuel accessibility of commercial energy has improved greatly in rural, but fuel affordability is still fragile, and soil fuel is mainly used by low income households, government can offer some fuel subsidy to household that the per capita income below poverty line, which is a proper form of poverty alleviation.

Acknowledgments: We thank the financial supports from China's National Key R&D Program (2016YFA0602801, 2016YFA0602603), National Natural Science Foundation of China (No. 71322306, 71273027, 71521002, 71673026, 71642004), Program for New Century Excellent Talents in University of Ministry of Education of China (No. NCET-13-0040), and Fok Ying Tung Education Foundation. We appreciate the comments from Xin Tang, Xiaoying Hu, Yueyi Li, and the help of local officials and residents. The views expressed in this paper are solely authors' own and do not necessarily reflect the views of the supporting agencies and authors' affiliations. The authors alone are responsible for any remaining deficiencies.

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