

Analysis on energy consumption of rural building based on survey in northern China

Xu Juan ^{a,*}, Gao Weijun ^b, Huoxiaoping ^a

^a The Department of Architecture, Chang'an University, Xi'an 701165, China

^b Department of Architecture, The University of Kitakyushu, Kitakyushu 808-0135, Japan



ARTICLE INFO

Article history:

Received 26 January 2018

Revised 17 August 2018

Accepted 17 August 2018

Available online xxxx

Keywords:

Energy consumption (EC)

Energy efficiency

Rural in North China

Energy usage behavior

Energy structure

ABSTRACT

Rural energy consumption is an important component of national energy consumption and plays an important role in rural areas and ecological environment developments. This paper investigated energy structure and energy usage behavior in rural areas of northern China based on the analysis of large-scale field survey data. The energy consumption structure is composed of the biomass energy and commercial energy, supplemented by two kinds of mutual use of the way. And Low efficient energy usage and poor indoor environment are major problems in this area. Therefore, the reason for the excessive energy consumption is poor thermal performance of construction, lack of planning standards and low energy efficiency. This paper provides new insights for north China's rural energy consumption, it can also provide detail and real data for the local decision makers and other stakeholders to promote energy-saving policy.

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Introduction

With the rapid social and economic development, the improvement of living quality requirements also leads to dramatic increase of energy consumption (EC). The construction industry and the scale of rural building area are also steadily growing year by year. The rural building kept rising during the past few decades and it will be the largest energy consumer in China. If the fast-growing building EC cannot be controlled, it will bring negative effects to the sustainable development of Chinese national economy, which remains the top priority in developing countries (CNBS, 2010). In the long run, the work above is far from enough. Accelerating the development of rural building energy efficiency has strategic meanings to improve people's living levels, to reduce EC, to improve environment quality and even to promote economic development. Chinese researches on rural building energy problems began from the 20th century and have achieved abundant fruits (Wang, Li, Chen, et al., 2009). In rural areas of China, basic energy demand for daily life is satisfied by biomass energies (Zhuang, Li, & Chen, 2009; Zhuang, Li, Chen, & Guo, 2009; IEA, 2016; Yang, 2010). Rural building EC mainly refers to energies used for daily life of rural building activities, including illuminating, cooking, heating, hot water supplying and building appliances using (Sameer, Anish, Anna, et al., 2016; Niu, Zhang, Zhao, et al., 2011; Shonali & Jiang, 2008).

Although there are several studies based on rural EC survey data, their sample size is relative small and there is little discussion on the types and usage behavior of REC. They did not present valid strategy that focus on current situation of EC. Therefore, the current research is either based on the analysis of macro data, or focused on a specific area without province level data of rural EC (IEA, 2016; Niu et al., 2011; Wu, Liu, & Li, 2010). The northern China is a huge geographical region with widespread village, where is very cold in winter and the heating demand requires larger load, leading to the total spending power of rural building higher than other regions in China. Meanwhile, rural buildings have specific characteristics in different regions due to the multiple influences of climate environment, economic level, living habits and quality.

Methodology

Survey design and aim

The current situation of EC in rural building is mainly related to location, architecture design, energy structure, and energy usage behavior of occupants (Baoping, 2016). In order to understand the situation of EC, the survey of coverage areas were designed with content including all provinces in northern China except Xinjiang and Nei Menggu. A summary of questions is presented in Fig. 1. Questions are included in the survey detailed questions on EC structure, behavior and the indoor comfort level was designed.

* Corresponding author.

E-mail address: xujuan0626@chd.edu.cn (X. Juan).

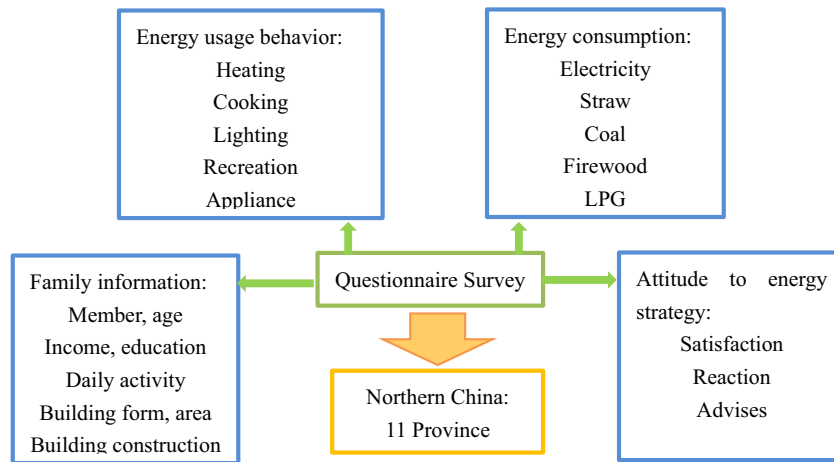


Fig. 1. The design of the survey questionnaire.

Survey methods and data

In order to further understand the changes of rural building EC in north China in recent years, Chang'a University of architecture school organized a large-scale survey. The sample selection process is as follows. In the two years of 2015–2016, Firstly, this paper obtained basic information on rural EC through field investigation and face-to-face interviews about 11 provinces in the northern China at randomly. Then selected two cities from each selected province and selected 5 or 6 villages from each selected city randomly. Lastly, 5 or 6 peasant buildings were selected from the each selected villages so that ensure each city with a survey of 30 samples and each province with 60 samples. According to the data of survey, the author used 'bottom to up' statistic method and 'top-down' check way to analyzed the rural residential condition and different classification of energy use, amount of EC in north China. There are 6 investigation teams with more than 60 students and teachers participated in this research after training. The survey method adopted three classes of province, city and village sampling. The range of the survey covered most of northern provinces, including Hebei, Henan, Shaanxi, Shanxi, Shandong, Jilin, Liaoning, Heilongjiang, Qinghai, Gansu, Ningxia and other 11 provinces. The content of the research mainly includes rural EC and the status quo, the situation and trend of rural renewable energy use, rural residential energy use, the ecological environment and resources comprehensive utilization, the situation and demand of the rural economy, technical information and industry development, etc.

There were 660 questionnaires have been completed. It reflected the overall situation of rural EC and changes of 10 years in rural area of northern China in 2016. And then use the combined method of quantitative field collection and qualitative data analysis to summarized situation of the EC and analyzed energy usage behavior. The result is absolutely true and reliable.

Results

The commercial EC in rural is significantly lower than that in downtown area, especially in northern China. However, if including the biomass EC, the total EC is similar between rural area and downtown area. According to the survey, the average building EC in rural of northern China is 27.4 kgce/(m²a). Due to the higher heating energy usage in the north, the amount of EC per square meter per year is more than double of that in southern China.

Energy consumption situation

According to the sample of the provincial average index as the standard, the rural population and the number of building in

'China statistical yearbook 2016' and the provinces in the yearbook, it can be calculated that the total living EC in northern China is 1.652 billion tce. per year. Coal, liquefied petroleum gas (LPG) and electricity are the commercial energy that must be paid, and the farmers have determined the EC based on their payment records (Shortall & Davidsdottir, 2017). For non-commercial energy, the types, quantities and densities of each firewood and straw estimate the consumption of wood and straw. According to the survey results show that coal, firewood, straw, liquefied petroleum gas, electricity is the main fuel use of rural buildings. In the calculation of EC, the electricity is different with other various energy sources which it can be calculated. The amount of electricity is converted in coal-fired power (kgce) which based on the annual coal consumption. The other types of energy are converted based on the average lowest heat of fuel (The values were set at 0.71 kgce/kg, 0.6 kgce/kg, 0.5 kgce/kg, 1.71 kgce/kg, and 0.33 kgce/kWh are represented the conversion coefficients to standard coal from raw coal, firewood, straw, LPG, and electricity, respectively. 1 kWh electricity = 0.33 kgce; 1 kg coal = 0.71 kgce; 1 kg LPG = 1.71 kgce; 1 kg firewood = 0.6 kgce; 1 kg straw = 0.5 kgce). The total EC of rural building is difficult to calculate with a unified standard. Therefore, all EC of energy conversion to standard tons of coal equivalent (tce, 1 tce = 29.3 GJ), in addition to electricity, according to the ratio of coal consumption and power generation, converted to coal consumption of power plants. Table 1 shows in the rural construction, commodity coal is 127 million tons (convert into 90 million tce). LEG is 1.673 million tons (convert into 002.8 million tce). Electricity is 56.84 billion kWh (convert into 19 million tce). The total of non-commercial biomass energy(including firewood and straw) is 93 million tce (convert into 53 million tce). Commercial energy and noncommercial energy accounted for 68.87% and 31.13% respectively. It can be concluded that the commercial EC accounts high proportion of total EC in the north region.

Changes of REC nearly 10 years

Table 2 shows that comparative analysis on different energy consumption source of rural life in each province of northern China. The decade between 2008 with 2016, the total number of buildings dropped from 72 million to 69 million, decreasing by 4.81%. However, since rural building upgrading, namely the growth of per capita building area, rural construction area grew from 7.27 billion square meters to 7.29 billion square meters, increasing by 0.41%. Total EC increases from 157 million tce in 2008 to 165 million tce in 2016, increasing by 5.09%. The commercial EC increased from 108 million tce to 112 million tce with growth rate of 3.7%, which is slightly lower than the total EC growth rate. Noncommercial EC increased from

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