Rural Household Energy Consumption Investigation and Structural Pattern Analysis of Xuanwei study area in Central Yunnan

Yuan Ling 1,3, Gan Shu 1,2*, Li Wenchang 1, HU Lin 1.
1 Land Resources and Engineering Faculty, Kunming University of Science and Technology, Kunming, Yunnan, 650011, China
2 Plateau Mountain Survey Technique Application Engineering Research Center at Yunnan Province's Universities, Kunming, Yunnan, 650011, China
3 Yunnan Energy Investment Group Co., Ltd, Kunming, Yunnan, 650093, China
*Correspondence Author Gan Shu's e-mail: 1193887560@qq.com

Abstracts. Rural household energy utilization is an important consumption that related to the survival and development of regional rural residents. With the deepening of the strategy of poverty alleviation and rural revitalization in China, the problem of energy consumption in rural households has become the focus of attention. In this paper, Xuanwei County, which is typical representative in Central Yunnan, is selected as the research case. Through the field investigation and questionnaire survey, the energy consumption status and structure pattern of rural households in the mountainous areas of the Central Yunnan Plateau are analysed and studied by using the methods of statistical perspective analysis and data induction and sort out. The main results are as follows: 1) In Central Yunnan, the current situation of rural household energy consumption is belong to the "electricity+" hybrid basic structure pattern, which is mainly based on electricity and combined with coal, fuel-wood, straw and so on to be of the diversified structure energy consumption characteristic. 2) Though there are 13 kinds of rural household energy consumption hybrid patterns in the study area, but only six kinds is found belong to dominant hybrid energy utilization structure patterns, namely, "electric-coal-firewood", "electric-firewood-straw" and "electric-coal-straw", "electric-firewood" and "electric-coal", as well as "single electricity" utilization type of energy mixed mode. In general, through the rural household energy investigation analysis is only completed in Xuanwei case, the general characteristics and its structural pattern in Central Yunnan can been obtained in the same thing. So the results will be helpful to guide the formulation of rural energy policy and management optimal utilization of regional rural energy in Central Yunnan and promote the implementation of National Rural Revitalization and Precision Poverty Alleviation Strategy.

1. Introduction
Rural household energy use is an important part of rural energy consumption, and its main uses include all kinds of energy consumed to meet the living needs of household cooking, lighting, heating, hot water, cultural entertainment and so on[1] . The rural energy consumption problem is closely related to regional social and economic poverty[2] . The issue of rural living energy and its poverty is also an important aspect closely related to regional poverty alleviation and understanding of regional
socio-economic sustainable development[3] . Energy poverty alleviation is also frequently cited by international development organizations as a necessary measure of income poverty reduction, such as the definition of a regional energy poverty line, most commonly measured by the conversion of the minimum amount of energy needed for cooking and lighting as a necessary part of the maintenance of the human body[4] [5] .

At present, many studies have pointed out that the consumption structure of rural living energy has significant differences in different stages and regions, and is closely related to regional resource endowment, climate conditions, economic conditions, social structure, regional culture and other factors[6] [8] . Adopting diversification strategy is considered as the best choice to ensure the security of long-term energy supply[9] . In China, the energy consumption of rural life is very different in different periods and regions, so choosing typical regions to carry out research is an important means to understand rural energy consumption and utilization characteristics. Central Yunnan refers to the vast plateau mountainous region located in Central Yunnan, which belongs to the area of Yunnan's rapid social and economic development and population agglomeration. In this paper, Xuanwei County is selected as a case to carry out to investigate and analyze, the main purpose is to understand the basic situation of rural energy consumption and utilization, and to reveal the structure and pattern characteristics of energy use. This study work will be of great practical significance for deepening the research on rural energy issues, guiding the formulation of regional rural energy policy, promoting the harmonious development of energy, environment and ecology in rural areas, and implementing the national strategy of precision poverty alleviation and rural revitalization.

2. Study area and investigation implementation

2.1. Study area
Xuanwei is located in the northeast of the Central Yunnan Plateau as shown in Figure 1. It is a county-level city under the jurisdiction of Qujing City, Yunnan Province, and far from Kunming about 204 km. The geological environment of Xuanwei is mainly the slope zone of the transition from Yunnan Plateau to Guizhou Plateau. The climate has the monsoon climate of low latitude plateau with many climatic zones, such as north subtropical zone, south temperate zone and middle temperate zone. In terms of social and economic characteristics, Xuanwei rural economy is generally poor and belong the national poverty alleviation county.

2.2. Sample survey on rural households energy consumption and utilization
The household sample survey subject requirements should include the basic information of the surveyed households and the thematic information on household choice of energy consumption utilization[10] . In this study, the survey was carried out mainly through field interviews after designing a special questionnaire. The selection of survey subjects adopts the method of stratified random sampling, the specific operation is first according to the local classification of the mountain area, semi-mountain area and basin area, based on the preliminary investigation and knowing of the overall situation of the number and type of rural distribution in the study area. Finally, a total of 332 rural households in 13 villages with typical representative study area were selected for sample survey.

Among the survey work, the basic information includes as the name of the head of household, the number of households, the age of the head of household, the status of non-agricultural sideline, etc. The thematic survey on energy consumption and utilization is conducted through a design sample survey. The main fields and related requirements are include as monthly electricity consumption, annual coal consumption, annual gas consumption, annual firewood, annual straw or other bioenergy, solar water heaters and other energy-saving measures for households, as well as the grading description survey fields corresponding to household income levels.
3. Data collection and analysis of energy consumption on sample survey

3.1. Collation and analysis of survey results on commercial energy consumption

According to the different regional zone types of mountain, semi-mountain and basin areas in the sample survey, the first focus is on the situation of commodity energy consumption and utilization, the results are listed in Table 1.

| regional Type  | sampled households Number | Electric fee of Annual Household | Electric+Gas fee of Annual Household | Electric+Gas+Coal fee of Annual Household |
|---------------|--------------------------|---------------------------------|-------------------------------------|----------------------------------------|
| Mountains     | 144                      | 787.50                          | 800.83                              | 1481.59                                |
| semi-mountain | 128                      | 853.78                          | 865.11                              | 1093.70                                |
| Basin area    | 60                       | 1106.00                         | 1155.00                             | 1394.18                                |
| Overall       | 332                      | 870.61                          | 889.47                              | 1316.10                                |

According to the results of preliminary analysis and investigation, it is concluded that with the gradual improvement of the power grid project in the study area under the national energy benefit policy, it has become a reality to electrify the village and the household. At present, there are no un-electricity households in the study area. Such as the Electric fee average annual consumption expenditure level of rural households in mountainous, semi-mountain and basin areas is between 787~1106 Yuan. In general, the comparative analysis of the annual household average energy consumption and utilization expenditure level in mountainous, semi-mountain and basin areas shows that the electricity consumption expenditure level and the clean energy consumption expenditure level are the characteristics of the basin area > semi-mountain > mountain area, but the commodity energy consumption level including coal consumption is different and the opposite. Based on the actual investigation and analysis of the reasons, farmers in the semi-mountain area generally have more energy resource types and diversity than the mountain area and basin area.

| Statistical features | Electric fee /per person. year | Electric+gas fee /per person. year | Electric+gas+coal fee /per person. year |
|---------------------|--------------------------------|-----------------------------------|----------------------------------------|
| Average             | 227.04                         | 231.88                            | 348.86                                 |
| Maximum             | 753                            | 788                               | 1240                                   |
| Minimum             | 45                             | 45                                | 45                                     |
| Deviation           | 105.47                         | 109.76                            | 169.20                                 |

In addition, based on the surveying, getting the average population of mountain families is 3.99, semi-mountain families is 3.91, basin area is 4.33, and the average population of the whole family in
the study area is 4.02. So according to the statistics of the annual per capita energy consumption expenditure level of the whole study area, the results show as Table 3: the annual per capita electricity consumption expenditure level is 227.04 Yuan, the annual per capita clean energy consumption expenditure level is 231.88 Yuan, and the annual per capita commodity energy consumption expenditure level is 327.36 Yuan. From the Table 2, looking the extreme value statistics and deviation parameters, it is quite different that the per capita consumption of rural households choosing different commodity energy combinations in the whole study area, especially the per capita expenditure level and variation status of choosing “electric+gas+coal” mixed mode are much higher than that of clean energy selection and utilization.

3.2. Survey and description of traditional bioenergy and solar energy utilization
In the same way, according to the different regional zone types of the study area, the traditional bioenergy consumption and utilization obtained from the survey were statistically sorted out in the mountainous area, semi-mountain area, basin area and the whole study area is statistics as Table 3.

| regional Type | sampled households Number | Annual household firewood kg | Annual household straw and other fuel kg | Annual local biomass energy kg |
|---------------|---------------------------|-----------------------------|----------------------------------------|-------------------------------|
| Mountains     | 144                       | 258.47                      | 54.83                                  | 313.30                        |
| Semi-Mountains| 128                       | 238.66                      | 62.74                                  | 301.40                        |
| Basin area    | 60                        | 9.17                        | 29.48                                  | 38.65                         |
| Overall       | 332                       | 205.78                      | 53.30                                  | 259.08                        |

The comparative analysis of the results shows that: 1) in the study area, the average annual household firewood consumption level is 205.78 kg, and the characteristics of the annual household average firewood consumption in different regional types are as follows: mountain area > semi-mountain area > basin area. There is a small difference between mountainous area and semi-mountain area, but the difference between basin area and mountainous area and semi-mountain area is obvious. The firewood used in basin area is very small. 2) The annual household straw consumption and other consumption in the study area is 53.30 kg, the overall regional level is household average annual household straw consumption and other physical consumption characteristics of different regional types of household average household straw consumption and other physical consumption characteristics are not very consistent with the use of firewood characteristics, the specific performance is semi-mountain > mountain > basin area. The amount of straw used by rural households in different regions is not as large as the amount of other objects, which is related to the distribution and utilization of cultivated land resources and the collection of straw.

4. Analysis on the Characteristics of Energy Consumption Patterns

4.1. Analysis on the Main Patterns of Energy Consumption Structure
The different energy combination patterns of rural life energy consumption and utilization of 332 households sampled in the study area are perspective analysis. The statistics result show that rural households in the study area for the type of consumption and utilization of living energy resources belong to the electric-based hybrid mode; The investigation appears 13 kinds of rural households energy utilization patterns as Figure2. It can got that 6 mode of the high frequency-proportional structure in the study area are as: 1) electricity-coal-firewood (25.93%), 2) electricity-firewood-straw (21.76%), 3) electricity (12.50%), 4) electricity-firewood (11.57%), 5) electricity-coal (10.65%), 6) electricity-coal-straw (9.72%); The proportion of households choosing these 6 energy-use combinations is as high as 93.06%, that is, only less than 7% of households choosing the remaining 7 energy-use combinations.

4.2. Analysis on commodity energy use characteristics of the main mode

In view of the energy use patterns of the six dominant combination, further statistical collation according to the consumption levels of electricity mode (clean commodity energy) and coal based on electricity mode (accumulated consumption on commodity energy consumption) are compared in view of the consistency of energy measurement units. Comparison of consumption levels of two different conditions is as Table 4.

| Six main pattern       | annual Per capita electricity fee | annual Per capita commodity energy cost (including coal) |
|------------------------|-----------------------------------|--------------------------------------------------------|
| Electricity            | 339.78                            | 339.78                                                 |
| Electricity - coal     | 301.84                            | 355.83                                                 |
| Electricity - coal - straw | 254.08                        | 362.01                                                 |
| Electricity - coal - firewood | 169.67                        | 417.76                                                 |
| Electricity - firewood | 169.16                            | 169.16                                                 |
| Electricity - firewood - straw | 162.29                        | 162.29                                                 |

From the preliminary analysis of this study area, it can be seen that the characteristic is especially obvious in the three energy consumption and utilization modes with coal participation combination, and there is generally a high level of household commodity energy expenditure. This result shows that rural households choose to use coal to participate in household commodity energy expenditure mix, which has obvious uneconomic characteristics of use.
5. Conclusion
At present, the main utilization types of rural household energy consumption in Central Yunnan case area include electricity, firewood, straw, coal and solar energy, and a small amount tanked LPG. Among them, the consumption level of commodity energy that needs expenses is 348.86 Yuan per year (including 227.04 Yuan of electricity expenses), while the amount of local biomass energy consumed by self-collection and utilization is about annual 259.08 per capita kg; There are some differences in the energy consumption level of peasant households in different regions, such as mountain area, semi-mountain area and basin area.

Especially with the implementation of the national policy of "Village Power Supply Project" for the benefit people in rural areas, the study area has realized the full coverage of rural household electricity utilization, so the energy consumption commonly is the "electricity+" combination structure model; among the 332 households sampled in the study area, though appeared 13 combination modes but more than 93% of the households' energy use structure belongs to the six dominant Hybrid energy model, namely as "electricity-coal-firewood", "electricity-firewood-straw", "electricity", "electricity-firewood", "electricity-coal" and "electricity-coal-straw".

In the study area, solar water heaters were widely used in sample survey households; liquefied gas only appeared sporadically in households with relatively rich rural economic conditions around the town to choose for cooking; and household biogas utilization was extremely rare because of the small overall size of rural households in mountainous areas, which were constrained by factors such as raw materials and labor costs.

In this study, according to the preliminary investigation, there are some differences in the rural household energy consumption patterns in the mountainous zone of the Central Yunnan Plateau. In addition, it is find that there has been relatively high economic cost of coal utilization in the study area and may be a potential environmental pollution and the risk of affecting the health of farmers, so it is suggested that the current energy use structure of the study area should be further optimized and adjusted to enhance the use of clean energy for electricity and reduce the combined use of coal selection. In general, rural households shown electricity substitution for coal and biomass in the choice and utilization of domestic energy consumption, but at present, due to the objective existence of regional rural economic poverty, the mixed structure model based on the integrated utilization of local bioenergy resources of electricity will continue to exist and play a role, and such energy consumption structure will not change in a short period of time, and the development of a variety of practical technologies should be encouraged to continue to strengthen household use of clean solar energy.

Acknowledgements
This study was supported by the National Natural Science Foundation of China (NSFC) project "Multi-scale Remote Sensing Detection and Analysis of Debris Flows in Dongchuan Xiaojiang "(41861054), and thank for getting help in the field investigation work by many graduate students come from the “Yunnan Province University Engineering Research Center of Spatial Information Surveying and Mapping Technology Application in Highland Mountain Area”.

References
[1] Zhou Z.R, Wang X.H, Chen Q, et al. (2007) A study on the evolution of energy consumption structure of well-off rural households in the north-Taking Huantai County of Shandong Province as an example. Journal of Agricultural Engineering, (3):192-197.
[2] Li K, Liu C.F, Wei Y.M. (2011) Analysis on the Current Situation of Energy Poverty in China. China Energy, 33(8):31-35.
[3] Wu Y.P, Zhang Y.(2017) Path selection and policy design of energy supply-side reform in china. Resource Development and Markets, 33(8).
[4] WHO. (2006) Fuel for Life-Household Energy and Health. Geneva: WHO.
[5] Smith K R. (2006) Health Impacts of Household Firewood Use in Developing Countries. Unasylva, 224(57):41-44.
[6] Liao H, Wei Y.M. (2010) The difference and imbalance of world energy consumption and its change research. Chinese Soft Science, (10):6-14.

[7] Zhai F.D. (2003) On adjustment of the rural energy development policy in China. Journal of Natural Resources, 18 (1):81-86.

[8] Wang X.H. Feng Z.M. (2005) Study on affecting factors and standard of rural household energy consumption in China. Renewable and Sustainable Energy Reviews, 9(1):101-110.

[9] Stirling A. (1994) Diversity and ignorance in electricity supply investment: addressing the solution rather than the problem. Energy Policy, 22(3):195-216.

[10] Zhang Z.C. (2014) A study on energy poverty in rural households-based on a questionnaire survey in Panxian County of the province. China Energy, 36(1):29-34.