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## Survey Research on Living Environment and Energy Consumption in the West Rural Areas of China

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### Abstract

In-situ questionnaire survey was done on living environment, heat insulation performance of envelopes and energy consumption in the west provinces—the poorest places of China. Survey results show that indoor temperature is very high in summer and very low in winter, so indoor environment is very bad and thereby has poor liveability in the rural areas of the China west. Moreover, the health of occupants is threatened due to poor air quality polluted by the livestock breeding, toilet sanitation, kitchen stove and so on. And there are poor heat insulation performances of envelopes, and even windows and doors have high heat conductivity coefficient and poor seal. If indoor thermal environment gains the same indoor comfort level with the urban buildings, energy consumption would increase more 3~5 times. Energy consumption survey shows that the base number of present rural energy consumption, which is very low, is 20% of urban energy consumption, but the rural buildings have the rapidly rising potential.

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**Keywords:** Retro-reflective materials; reflection; indoor temperature

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### 1. Introduction

China is a vast agricultural country and has a 0.674 billion rural population in 2010, which accounts for 50.32% of the total population in China. Meanwhile, China also has the building areas of 23400 million m<sup>2</sup>, which accounts

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for 50.70% of the total civil construction building area of China [1]. Therefore, the urbanization and the new countryside construction are always the long-term national policies of China's socialist construction [2,3]. In addition, although the China government devotes itself to the economic development of the west, China is still an imbalanced country between the west and the east. Especially in the west rural areas, living level is lower and indoor environment is poorer owing to their restriction of topography, physiognomy, climate and economic development [4]. According to the standard for poverty alleviation in 2011, the rural poverty population in the west has 63.45 million, which accounts for 21.9% of the total rural population and 51.9% of the total rural poverty population in China. It can be clearly found that more than half of rural poverty population live in the west area. Therefore, it is of important significance to refine the rural indoor environment and improve the local living level in the rural west areas for the economic balanced development and the social stability.

The research of Luo and Liu [5] shows that the rural poverty and the environmental degradation are two urgent problems faced in the China west based on the analysis of statistical data, and that the respiratory disease caused by the direct burning of solid fuel (such as straw and coal) has become the one of four killers leading to the death of rural population. Ma [6], Cui et al [7] and Wang & Wang [8] discussed the environmental conditions and their causes in China west rural areas respectively with the examples of Tianshui, Shanxi and Ningxia, and proposed the relative measures of the awareness, funding and base installation on the environmental protection. Zhu and Liu [9] proposed the indoor thermal environmental index of more than 15°C suiting to winter thermal comfortable temperature in the northwest rural areas, combining with the local rural building characters, winter dressing and life living habits. However, above research did some research and proposed some measures based on the rural environment, but most of them often took a city for an example and thereby lacked of the comprehensive and systemic study on the whole west. Particular in the China southwest, there are only a few papers. Therefore, it is necessary to do the further and systemic survey on the development status of the China west rural areas.

To reveal the statue of China west rural areas, our study organizes students to do the in-situ questionnaire survey by utilizing the summer practice in Sichuan University. Sichuan University, which locates in the southwest area, has the advantages of position and native place of students. This questionnaire survey refers to three main contents of living environment, wall heat insulation performance and energy consumption with the hope of the accurate knowledge about the west rural area.

## 2. Methods

### 2.1. The questionnaire survey process

In this study, the main method is the in-situ questionnaire survey with the help of the in-situ measurement. And the whole can be divided into some processes below:

- The questionnaire tables have referred to three main questions of living environment, heat insulation performance and energy consumption.
- The education was done on the indoor comfortable level, wall heat insulation and energy forms for the investigators to decrease the errors from human factors and increase the accuracy of survey data.
- In the in-situ survey, one group had two men, one of which was the question master and another wrote the answers from investigated objects. Meanwhile, in-situ measurement was done about wall thickness and indoor temperature, and some photos were taken.
- The survey questionnaires were checked and some of them were rejected due to the data mistake or inappropriate positions. And two men analyze those data statistically to decrease the statistical errors.

### 2.2. The survey analysis

In this survey, nine provinces are investigated including Chongqing, Sichuan, Yunnan, Guizhou, Shanxi, Gansu, Qinghai, Ningxia and Xinjiang. To simply the statistical analysis, the west can be divided into the southwest including Chongqing, Sichuan, Guizhou and Shanxi, and the northwest including Shanxi, Gansu, Qinghai, Ningxia and Xinjiang. There are the vast mountainous region and the complicated topography in the southwest, while there

are the vast highland region and the arid or semi-arid climate in the northwest. Table 1 shows the areal distribution of questionnaire positions. As shown in Table 1, Sichuan has maximum questionnaire tables; next is Xinjiang and Guizhou has minimum tables. And the northwest and the southwest have nearly the same percentages of 46.51% and 53.49%, respectively.

Table 1. The areal distribution of questionnaire positions.

Number	Provinces	Percentage	Position	Climate zone
1	Yunnan	11.40%	The southwest	The mild zone
2	Guizhou	8.51%	The southwest	The mild zone
3	Sichuan	15.83%	The southwest	The summer hot and winter cold zone
4	Chongqing	11.27%	The southwest	The summer hot and winter cold zone
5	Shanxi	10.99%	The northwest	The cold zone
6	Gansu	8.58%	The northwest	The cold zone

### 3. Results

Due to the vast area and the big climate difference of China west, the southwest has the summer hot and winter cold climate or mild climate, while the northwest has the cold climate or the severe cold climate. Therefore, the west can be divided into the southwest and the northwest in the below analysis on living environment, wall heat insulation and energy consumption.

#### 3.1 Investigation on the living environment

The living environment investigation has referred to two main contents on the indoor thermal environment and the specific air pollution of rural areas. Fig. 1 shows the evaluation on indoor thermal environment in the southwest and the northwest under (a) winter, (b) summer and (c) transition seasons. From Fig. 1(a) of winter, 70% of rural occupants consider that indoor air is “cold” or “cool” in the southwest, while more than 20% consider that indoor air is “cold” or “cool” in the northwest in spite of that there are adobe kang or man-made central heating equipments to refine indoor thermal environment. And from Fig. 1(b) of summer, more than 60% of rural occupants consider that indoor air is “hot” or “warm” in the southwest, while more than 40% consider that indoor air is “hot” or “warm” in the northwest. From Fig. 1(c) of transition seasons, indoor thermal environment is relatively good and habitable, but more than 20% think that indoor air is “warm” or “cool”. From the above, it can be easily found that indoor thermal environment is poor in the China west areas, and especially in the southwest, indoor air is hot in summer and cold in winter. If the stricter index ( $-0.45 \leq PMV \leq 0.45$ ,  $PPD \leq 10\%$ ) is used to evaluate indoor comfortable level, nearly no occupant is satisfied with indoor environment. No matter in summer or winter, indoor thermal environment is very poor in the rural buildings of China west.

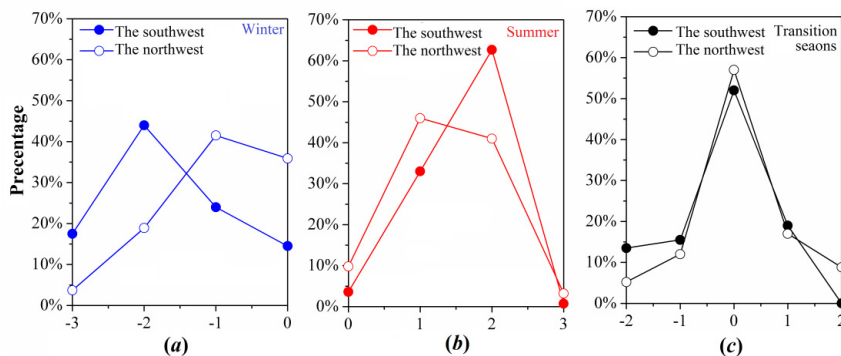


Fig. 1. Evaluation on indoor thermal environment in the southwest and the northwest under (a) winter; (b) summer and; (c) transition seasons.

Fig. 2 shows indoor air pollution in the southwest and the northwest. As shown in the Figure, due to the ambiguity of functional division and layout planning in the rural buildings of China west, the phenomenon of adjacency between occupants and domestic animals is very common. And this percentage is 58.14% in the southwest, while it reaches 42% in the northwest. It shows that indoor air quality is severely polluted. The phenomenon of no sanitation toilets is obvious and this percentage can reach 87% in the northwest, while it also can be up to more than 50% in the southwest. In addition, although the centralized treatment of rural waste is main content of the new countryside construction in China, the percentages of rural occupants, who reflect no centralized treatment of rural waste, can still reach to 40.18% in the south west and 23.13% in the northwest. Straw burning refers to on-site burning in the farmland and burning in the kitchen, and these percentages can reach to 48.23% in the southwest and 38.28% in the northwest. Straw burning in the farmland is expressly prohibited due to air pollution and soil destruction. When the strew is directly burning, there is smoky in the kitchen and the concentration of CO, SO<sub>2</sub> and inhalable particles is dozens or even hundreds of times more than the standard value. The published research has shown that strew burning in the kitchen can cause the chronic obstructive pneumonia, acute respiratory tract infections, lung cancer and so on. At present, the death number, which resulted from the respiratory diseases by the solid fuel burning, can count for 15%~25% [4].

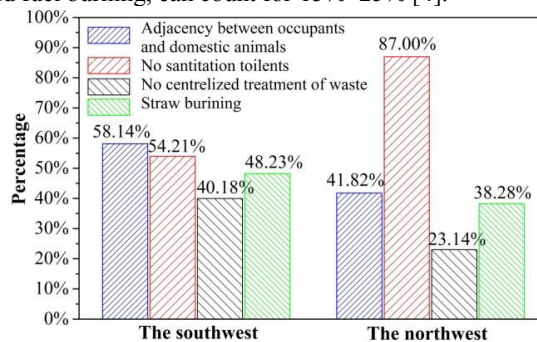


Fig. 2. Indoor air pollution in the southwest and the northwest

From the above, living environment is so poor and badly liveable that it is urgent to refine. And some bad phenomena threaten the health and safety of occupants severely such as indoor air pollution, the adjacency between occupants and domestic animals, no centralized treatment of rural waste, no sanitation toilets and so on. However, in the rural areas, there is high population density and vast vegetation, so it is necessary to further research why there is poor indoor thermal environment.

### 3.2 Investigation on wall heat insulation performance

Wall heat insulation performance affects the indoor environment livability and energy consumption of heating and air-conditioning in buildings. Therefore, in this questionnaire survey, wall heat insulation and the seal of windows and doors are main contents. Fig. 3 shows the thickness and materials of building walls. As shown in Fig.3(a), more than 60% of walls have 240mm thickness in the west. But there are many walls of 120mm, whose percentage is more than 26.42% in the southwest. Due to indoor heating of adobe kang or man-made central heating equipment, the wall thickness in the northwest is small larger than that in the southwest and there is only 4% walls of 120mm and 29.33% walls of 360mm in the northwest. In Fig. 3(b), the bricks have the high utilization rate of 62.5% in the southwest, in spite of their big heat conductivity coefficient and vast material consumption. In the northwest, wall materials are relative varying, but no any insulation layer can be found in the rural southwest. In the cold or severe cold zones, these materials and thickness of walls cannot create indoor comfortable environment.

Fig. 4 shows the material statistics of window frames and doors. As shown in Fig. 4(a), in the southwest, 83.5% of windows frames are made of aluminium alloy or wood. Aluminium alloy is good heat conductors with heat conductivity coefficient of 230W/(m·K), which can worsen indoor environment. On the other hand, in spite of low

heat conductivity coefficient, wood windows frames, which are made by local woodworker, have poor seal and thereby air infiltration volume is vast. Meanwhile, 49% of rural buildings also use aluminium alloy and wood windows frames. As seen, high heat conductivity coefficient and low sealing are main factors leading to the poor thermal environment. Fig. 4(b) also shows the same phenomenon with the Fig. 4(a). The utilization rate of wood doors research to 65.65% in the southwest and 31.75% in the north, while the utilization rate of metal doors research to 65.65% in the southwest and 31.75% in the north.

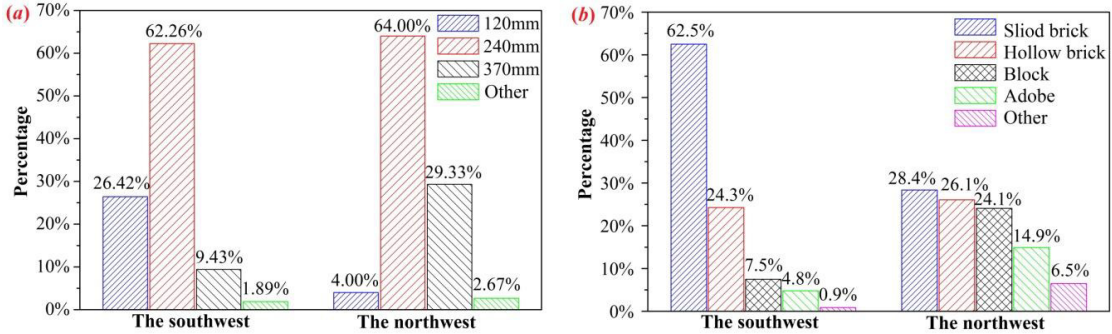


Fig. 3. (a) The thickness and; (b) materials of building walls.

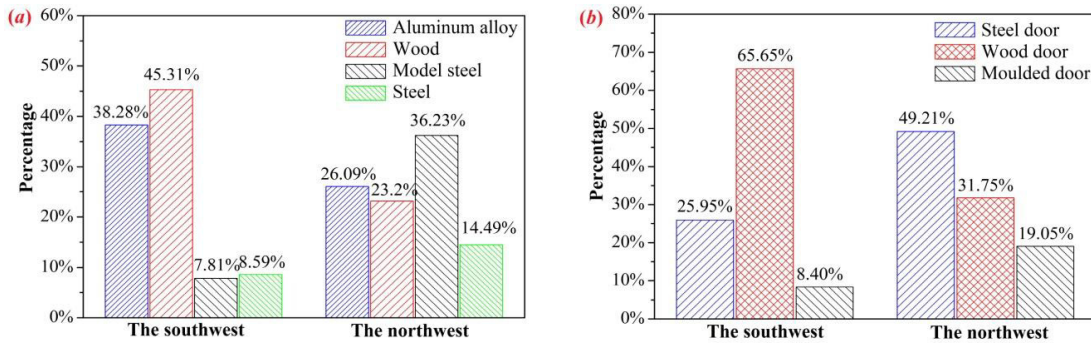


Fig. 4. (a) Window frame materials and; (b) door materials.

From above, it is easily found envelopes have poor heat insulation in China west. Especially in the windows and doors of buildings, there is high heat conductivity coefficient and vast air penetration. On the one hand, it shows the sources of poor indoor environment. On the other hand, it donates the present status of wall heat insulation. If indoor comfortable level is improved by heating and air-conditioning on the present situation, energy consumption would increase more 3~5 times than that in urban areas. Therefore, in the China urbanization and the new countryside construction, the prospective building energy saving must be promoted.

### 3.3 Investigation on building energy consumption

With the economic development, the building energy consumption has increased to more than 30% of the whole social energy consumption and the building energy saving has been one national policy in China. Therefore, it is necessary to make sure the contribution of rural buildings in the China west to the whole building energy consumption.

Fig. 5 shows the power consumption per area and the statistics of household appliances. As shown in Fig. 5(a), more than 65.4% of families consume less than 9kWh per area in a year in the southwest, while this percentage is more than 78.9% in the northwest. In the whole west, 90% ~95% of families consume less than 15kWh per area in a

year, which is 20% of that in the urban areas. And it shows that energy consumption in the west rural area is further lower than that in the urban areas. Is it necessary to promote the building energy saving? Fig. 5(b) show the statistic of household appliances. It can be found that the owning percentage of television reaches to 100% no matter in the southwest or the northwest. Due to the difference of region and climate, the owning percentage of fans is up to 100% and there are high percentages for refrigerators, washing machines, air conditioning and water dispenser in the southwest. And due to the influence of lacking of water, there are low percentages for equipments consuming water and high percentages for heating equipments. As seen, the universality and diversification of household appliances are a characteristic in the west rural areas. However, there is so low power consumption per area in a year. In the in-situ survey, high owning rate of household appliances is stimulated by the national consumptive policies about the home appliance subsidies for rural areas. And more household appliances have low utilization rate and become on display. Therefore, at the present rural areas of the China west, energy consumption only comforts the most basic living and the occupants are located in the survival need period. But with the economic development and the concept change, the household appliances with high owning percentage must be used frequently. So the energy consumption of the west rural area must increase rapidly.

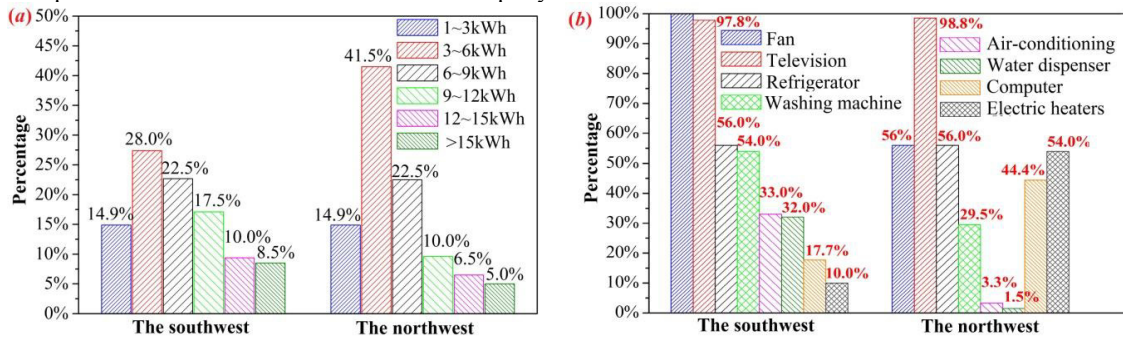


Fig. 5. (a) The power consumption per building area in a year and; (b) the statistics of household appliances.

Fig. 6 shows the energy types consumed in the China west rural areas. As shown in the figure, the electric energy has been universal. The wood and straw have high utilization rates in the southwest, where there are many mountains and farmlands, while the coal has high utilization rates of 76% and wood and straw have low utilization rates in the northwest, where there are coal mines and many livestock are raised. However, both wood and straw in the southwest and coals in the northwest are directly burned. And this utilization method pollutes the atmospheric environment and worsens indoor air quality. Actually, there are vast areas, rich solar energy, and many raw materials for biogas production from farmland and livestock in the rural areas. However, some suitable and new energy, such as biogas, solar energy, has low utilization rates.

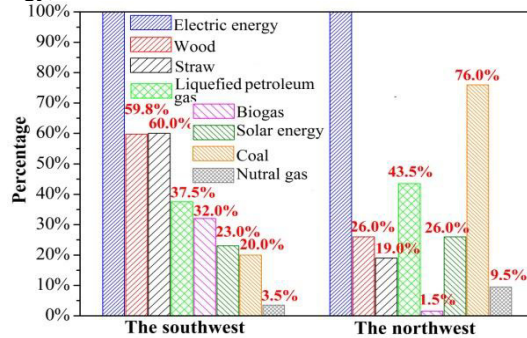


Fig. 6. The energy types consumed in China west rural area.

From the above survey, it is easily found that the energy consumption in the west rural areas is further lower than

that in the cities, but it has a potential of rapid increasing. With the promotion of China urbanization and the new countryside construction, the change of life way, and the improvement of living quality, the rural energy consumption must increase rapidly. On the other hand, the present energy consumption has low efficiency and primary utilization method and little utilization percentage of new and suitable energies.

#### 4. Discussion

In our study, in-situ questionnaire survey was done on living environment, wall heat insulation performance and energy consumption in the west provinces. Some following conclusions have obtained. More than 90% of occupants think that indoor environment is very bad and has poor liveability in the west rural areas. The health of occupants is threatened due to poor air quality, which is seriously polluted by the livestock breeding, toilet sanitation, kitchen stove and so on. And there is poor heat insulation performance in buildings due to the thin wall thickness and no heat insulation materials. And even windows and doors have high heat conductivity coefficients and poor seal. All those reasons lead to the above poor indoor thermal environment. And if indoor environment could gain the same indoor comfort level with the urban areas, energy consumption will increase more 3~5 times. The base number of present rural energy consumption, which is very low, is 20% of urban energy consumption, but the rural buildings have the rapidly rising potential. With the promotion of the urbanization and the new countryside construction, rural building energy consumption must increase significantly. Rural energy consumption has the low utilization coefficient and the primary utilization method. Meanwhile, new or renewable energy also has low utilization percentage. The prospective building energy saving must be promoted and the utilization of suitable or new energies must be strengthened in the urbanization and the new countryside construction by means of advantages in the west rural areas.

#### 5. Conclusions

Indoor environment is very poor due to the severe air pollution, poor heat insulation performance of building envelopes and the low seal of doors and windows. In addition, although the base number of present rural energy consumption is very low, the rural buildings have the rapidly rising potential. On the other hand, the utilization method has low efficiency and new or suitable energy has low utilization percentage, so the indoor environment improvement is an urgent task and the predictive building energy saving must be considered in the urbanization and the new countryside construction.

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