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Study on Supply and Demand of Cooking and Heating Energy in Rural Areas of Northern China

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Abstract: In China, rural residential energy consumption is affected by economic and social factors. Cooking and heating are the essential energy-using activities for the living in northern China and contributes most of the energy consumed in northern rural households. In this study based on data of rural energy consumption in 15 northern regions, some indices of energy supply and demand of rural cooking and heating are calculated. Results show that in northern rural households, fossil energy plays an important role in cooking and heating and the annual heat amount demanded for house-heating is always larger than for cooking. However, the energy-using efficiencies of rural heating and cooking need to be improved. For the comparison of provincial administratives, Beijing, Xinjiang and Shanxi are at the higher level of rural annual per capita energy-using while rural households in northeastern regions use more renewable energy (mainly crop residue) than other regions.

Key words: Rural energy, consumed energy, effective heat, integrated efficiency

INTRODUCTION

In recent years, the rural energy consumption in China keeps increasing because of the economic and social development. In 2009, 366.5 Mtoe of energy were consumed in rural China (Zhu, 2011), which contributed 25.6% of national energy consumption and 4.41% of global energy consumption (NBSC, 2012).

Constrained by the economic level, the rural residential energy consumption is mainly for basic need in China. In building thermal design zoning, almost the whole northern China is in cold zone and severe cold zone. Residents there need to heat their room in winter. Cooking and heating are the essential energy-using activities for the living in northern China and contributes most of the energy consumed in northern rural households.

Both cooking and heating use heat that released by burning fuels. Because of the efficiencies of energy-using appliances, the amount of heat received by the consumers is always less than the total energy amount contained in the energy resources. There are various patterns of cooking and heating in rural area, but the thermal efficiencies are lower than that in urban area. In order to improve the energy efficiency and relieve the pressure of fossil energy supplement, it is urgent to develop rural energy planning based on renewable energy technologies. Both the data of consumed energy resources and received energy amount are requested for rural energy planning, in order to determine the system scale and feasibility. As the main energy-using activities of rural households in northern China, cooking and heating should be paid great attention and studied in both terms of supply and demand.

Most of the existing research on rural energy issues in northern China took cooking and heating as an integrated part of residential energy-using. By focused on not only the consumed energy resources but also the distribution of energy resources in cooking and heating, a few researchers obtained detailed results on energy structures of some rural areas in northern China. Ning *et al*. (2012) investigated and analyzed the framework of energy consumption in rural households throughout northeastern China. They found that straw and firewood, which together accounted for 68.8~78.3% of all energy consumption, were energetic categories that most largely used in residences, besides, cooking and heating accounted for 64.0~95.4% of all residential energy consumption. Zhou *et al*. (2007) analyzed the evolvement of rural household energy consumption structure in a typical comparatively well-off countryside in a County of Shandong province. They concluded that coal

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consumption increased and dominated in all energy sources and energy consumption of cooking and heating became nearly equivalent while cooking energy consumption dominated in the past. Li (2007) defined the "energy-ecology-economy system" and took rural household in loess hilly region in Gansu province as the study area. He deeply analyzed the potential of energy resource development, such as household energy structure, impact on local environment, economic cost of energy consumption, etc. Finally he pointed out the way of optimizing the energy-ecology-economy system in that region. Though the achievements above have made some progress while other studies were solely on the amount of energy consumption, they paid no attention to the effective heat of cooking and heating demand. Besides, the scales of them are limited in some particular areas.

In this study, based on the data from surveys and statistics, the supply and demand of cooking and heating energy of rural households in northern China are studied through the calculation of annual indices such as consumed energy, effective heat, integrated efficiency, etc. The conclusion provides reference information for rational planning and utilization of rural energy.

MATERIALS AND METHODS

Rural energy data of different regions in northern China are collected from surveys and statistics. The units of fuels are converted to a unit of energy. Then the amounts of effective heat received by users are calculated according to energy efficiencies of appliances. Finally a series of rural energy indices in northern China can be derived, some of which are compared to those of urban households.

Calculating methods of energy supply and demand: This study takes consumed energy as the main index for energy supply and effective heat for energy demand. The consumed energy is defined as the total amount of energy contained in the consumed resources. The effective heat is defined as the amount of heat received by consumers, which equals to the amount of heat delivered to consumers by appliances.

Supposing that the consumption amount of a type of energy resource is M [t], v is the corresponding calorific value [GJ/t], thus the consumed energy (E) is [GJ]:

$$E = Mv \quad (1)$$

Taking into account the thermal efficiency of the appliance corresponding to this type of energy (η), then the effective heat (H) is [GJ]:

$$H = E\eta \quad (2)$$

Supposing n types of energy resources are consumed, the integrated efficiency (η_n) is defined as the ratio of total effective heat to total consumed energy of the n types of energy resources. η_n is calculated as:

$$\eta_n = \frac{\sum_{i}^{n} H_i}{\sum_{i}^{n} E_i} \quad (3)$$

Basic data: For cooking and heating in rural areas in northern China, most residents combust fuels in their own houses and use the released heat. The energy-using appliances and energy resources that most commonly used for cooking and heating by rural households in northern China are selected in the study.

The calorific values of energy resources and thermal efficiencies of energy-using appliances are listed in Table 1 and 2.

Currently, the consumptions of firewood and crop residue are not included in national statistics of China. 2012 Annual Report on China Building Energy Efficiency, written by (Building Energy Research Center of Tsinghua University, 2012) contains surveys on rural residential energy consumption in all 15 provincial administrative of northern China. The detailed data from the surveys, as an example shown in Table 3, are taken as the basic energy consumption data for the calculation of energy indices of rural cooking and heating. Other basic data for the study are taken from related statistical yearbooks.

Table 1: Calorific values of energy resources for rural cooking and heating in Northern China (NBSC, 2012)

Energy type	Calorific values [GJ/t]
Firewood	16.726
Crop residue	14.654
Coal	20.908
LPG	50.179

Table 2: Thermal efficiencies of energy-using appliances for rural cooking and heating in Northern China

Appliance type	Thermal efficiency
Biomass stove for cooking	10% (Guo, 2010)
Coal stove for cooking	13% (Wu *et al.*, 1988)
LPG stove for cooking	55% (CNS, 2007)
Kang (with biomass stove) for heating	45% (Guo, 2010)
Kang-indigenous heating system (with coal stove) for heating	70% (Zhao, 2009)

Table 3: Annual energy consumption data in cooking and heating of rural households in Beijing [10^4t]

Item	Firewood	Crop residue	Coal	LPG
Cooking	7.8	18.7	178.5	4.9
Heating	17.8	14.9	383.4	0.0

RESULTS AND DISCUSSION

General annual characteristics: In northern China, the annual consumed energy of rural cooking and heating is larger than urban residential consumed energy, regardless of the total or per capita amount Table 4. Since the residential consumed energy includes not only cooking and heating but also lighting, entertainment, etc., which attribute significant proportions, the consumed energy of cooking and heating of urban households is significantly less than that of rural households. The total and per capita consumed energy of rural cooking and heating contributed by fossil energy are also shown in Table 4. The total fossil consumed energy of rural cooking and heating is 1.65 times of the urban residential consumed energy (3.40/2.06 = 1.65), but the ratio of per capita amount drops to 1.11 because of the larger rural population (9.12/8.21 = 1.11). That means in northern China, residential consumption in rural area contributes higher pressure on regional supply of fossil energy than that in urban area.

In rural area of northern China, the consumed energy of heating is 1.74 times of that of cooking (Table 5, 3.04/1.75 = 1.74) but the ratio of effective heat rises to 7.26 because of the higher integrated efficiency of heating (1.67/0.23 = 7.26). Therefore, a conclusion can be drawn that heating is the primary energy demand of rural households in northern China.

Fossil energy accounts for about 71% of total consumed energy and more than 93% of total effective heat of rural cooking and heating in northern China (Table 6, 3.40/4.79 = 70.98%, 1.77/1.90 = 93.16%). The two ratios show the great dependence on fossil energy of northern rural households. However, the integrated efficiency of renewable energy is significantly low while the integrated efficiency of fossil energy needs to be improved as well.

Annual per capita characteristics by region: The annual per capita consumed energy of rural cooking and heating in Beijing, Heilongjiang, Shanxi, Xinjiang and Liaoning are larger than that in other northern regions (Fig. 1a). Henan has the minimum annual per capita consumed energy both of rural heating and total and it's the only region in which the annual per capita consumed energy of rural heating is less than that of rural cooking. In every region except for Henan, the ratio of annual per capita consumed energy of rural heating in total is about 60~70% (Fig. 2a).

Comparing to the study by Ning *et al.* (2012), in the northeastern region (Liaoning, Jilin and Heilongjiang), the total rural annual per capita consumed energy in this study doesn't have considerable difference, but the amounts of cooking in 3 provinces are all relatively low while those of heating are all relatively high (Table 7).

Table 4: Consumed energy of rural cooking and heating and urban residential consumed energy in Northern China [GJ/a]

Values	Consumed energy of rural cooking and heating	Fossil consumed energy of rural cooking and heating	Urban residential consumed energy
Total	4.79×10^9	3.40×10^9	2.06×10^9
Per capita	12.85	9.12	8.21

Table 5: Energy-using of rural cooking and heating in Northern China

Energy type	Consumed energy [10^9GJ/a]	Effective heat [10^9GJ/a]	Integrated efficiency(%)
Cooking	1.75	0.23	13.29
Heating	3.04	1.67	55.01
Total	4.79	1.90	39.77

Table 6: Fossil/Renewable energy-using of rural cooking and heating in Northern China

Energy type	Consumed energy [10^9GJ/a]	Effective heat [10^9GJ/a]	Integrated efficiency(%)
Fossil energy	3.40	1.77	51.95
Renewable energy	1.39	0.14	10.00
Total	4.79	1.90	39.77

Table 7: Comparison of rural annual per capita consumed energy in Northeastern Region [GJ]

	Cooking		Heating		Total	
Region	This study	Ning *et al.* (2012)	This study	Ning *et al.* (2012)	This study	Ning *et al.* (2012)
L	8.2	10.1	12.1	7.2	20.3	17.3
J	5.0	7.4	9.0	8.2	14.1	15.6
H	7.6	13.9	20.0	9.0	27.6	23.0

L: Liaoning, J: Jilin, H: Heilongjiang

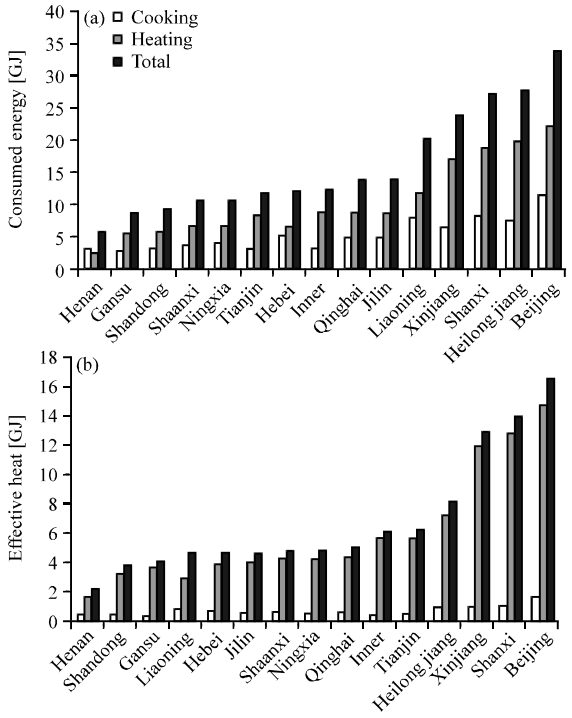

Fig. 1(a-b): Annual per capita consumed energy and effective heat of rural cooking and heating, (a) Consumed energy and (b) Effective heat

This may be caused by different classification of the consumed energy for winter cooking: in order to save heating cost, if not extremely cold, some households use the heat from cooking energy for space heating.

In Beijing, Shanxi and Xinjiang, the annual per capita effective heat of whether rural heating or total is significantly larger than that in other northern regions while these two indices in Henan are both the least (Fig. 1b). Beijing, Shanxi, Liaoning, Heilongjiang and Xinjiang have significantly larger annual per capita effective heat of rural cooking. In every northern region, 80~95% of the rural annual per capita effective heat is of heating (Fig. 2b), thus indicating that rural households in all northern regions always demand much more heat yearly for heating than for cooking.

In Beijing, Shanxi and Xinjiang, the fossil annual per capita consumed energy of both rural cooking and heating are significantly larger than those in other northern regions. In Liaoning, Jilin and Tianjin, the fossil annual per capita consumed energy of rural cooking are significantly less than that in others (Fig. 3). In every region except Henan, 60~90% of the rural fossil annual per capita consumed energy is for heating (Fig. 4).

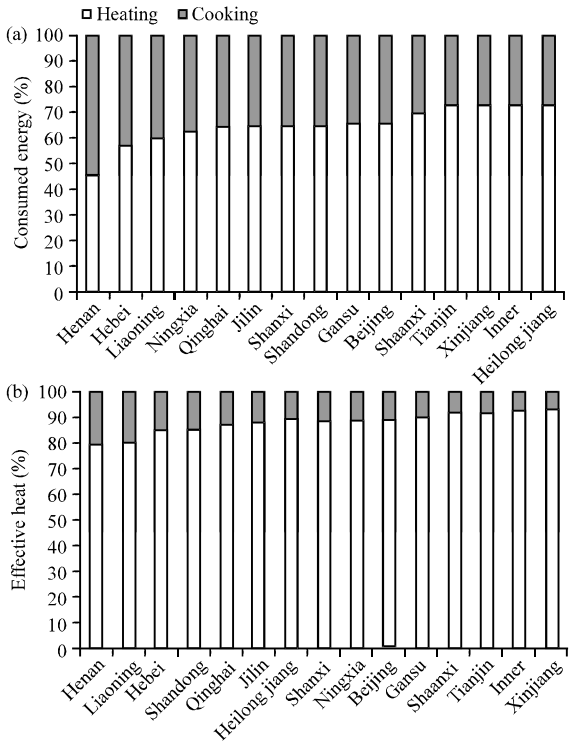

Fig. 2(a-b): Distribution ratio of cooking and heating in rural annual per capita consumed energy and effective heat, (a) Consumed energy and (b) Effective heat

Considering that all fossil energies in rural area are commercial energies, it can be inferred that for most rural households in northern China, energy costs are mostly spent on heating.

Among the northern regions, the ratios of rural fossil annual per capita consumed energy in cooking vary more greatly than that in heating (Fig. 5). In northeastern regions (Liaoning, Jilin and Heilongjiang), both the two ratios are less than that in others, thus indicating that renewable energy (mainly crop residue) still plays an important role in rural residential energy-using in northeastern China. This finding can be supported by the previous study by Ning *et al.* (2012), described in BRIEF introduction of this study. At the other side, both the two ratios in Xinjiang, Beijing and Shanxi are at higher levels.

The integrated efficiencies of both fossil and total energy in every northern region are illustrated in Fig. 6. It can be seen that the northeastern regions (Liaoning, Jilin and Heilongjiang) have higher fossil energy integrated efficiencies but lower total energy integrated efficiencies. Related to the thermal efficiencies

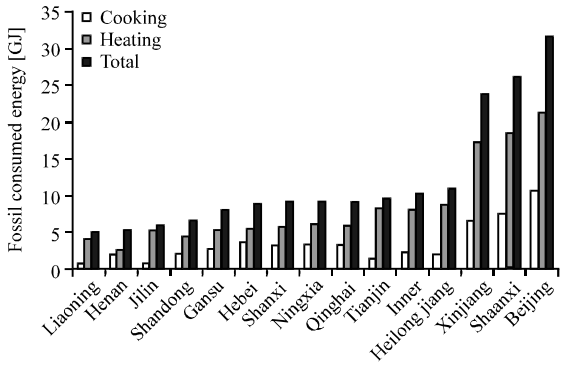

Fig. 3: Fossil annual per capita consumed energy of rural cooking and heating

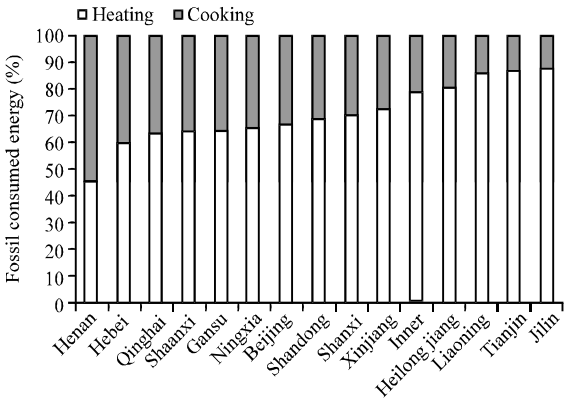

Fig. 4: Distribution ratio of cooking and heating in rural fossil annual per capita consumed energy

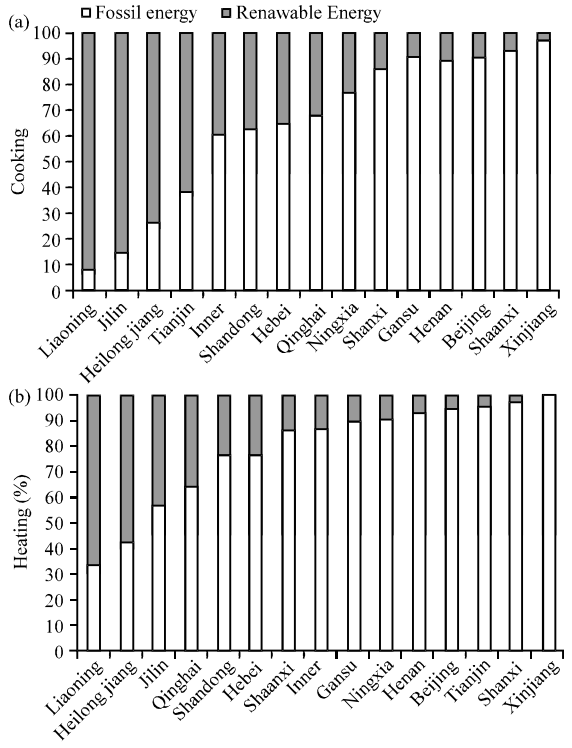

Fig. 5(a-b): Distribution ratio of fossil and renewable energies in rural cooking and heating annual per capita consumed energy, (a) Cooking and (b) Heating

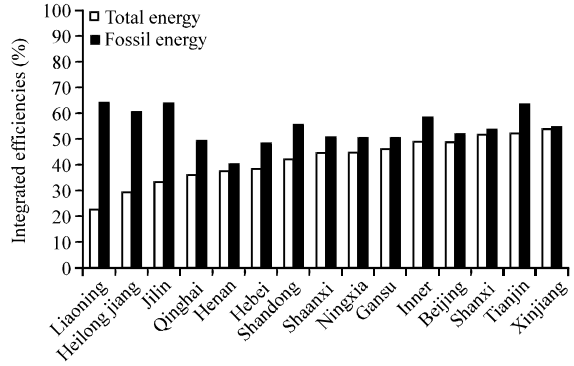

Fig. 6: Integrated efficiencies of both fossil and total energy

in Table 1, it can be inferred that in northeastern rural households, biomass stoves are commonly used for cooking while coal stoves are commonly used for heating.

CONCLUSION

Comparing to the study before, this study takes all the 15 northern regions of China as the study area and paid attention to the effective heat of cooking and heating demand. Through the calculation and analysis of consumed energy, effective heat and integrated efficiency of rural cooking and heating, some conclusions about rural energy supply and demand in northern China can be drawn as follows:

- Northern rural households depend greatly on fossil energy in cooking and heating. Residential consumption in northern rural area contributes higher pressure on regional supply of fossil energy than that in northern urban area
- Northern rural households always demand much more heat yearly for heating than for cooking and energy costs in most rural households are spent on heating
- The efficiencies of both renewable and fossil energy need to be improved
- For many indices, Beijing, Xinjiang and Shanxi are at the highest level than other northern regions. These indices include annual per capita consumed energy, effective heat, fossil consumed energy and ratio of fossil consumed energy
- For rural households in northeastern regions (Liaoning, Jilin and Heilongjiang), renewable energy (mainly crop residue) plays an important role in energy-using and is mostly consumed for cooking, while coal is mostly for heating

REFERENCES

Building Energy Research Center of Tsinghua University, 2012. Annual report on China building energy efficiency, 2012. China Architecture and Building Press, Beijing.

CNS, 2007. Domestic gas cooking appliances. Chinese National Standards, Standard Number: GB 16410-2007, Code of China Inc., China.

Guo, J., 2010. High-performance prefabricated and assembled elevated-kang-and-cooking-stove unit. Agricultural Engineering Technology, Renewable Energy Industry, pp: 1-5.

Li, G., 2007. Study on eco-economic system of rural household energy: A case of loess hilly region in gansu province. Ph.D. Thesis, Lanzhou University, China.

NBSC, 2012. China Energy Statistical Yearbook 2012. China Statistics Press, Beijing, China.

Ning, Y., Y. Li, T. Ding and Y. Tonooka, 2012. A survey on energy consumption in rural households in North-East China. Sustainable Energy, 2: 76-81.

Wu, A., Y. Li and Q. Cai, 1988. The thermal efficiency experimental methods of household combi-coal-stoves. Energy Conserv. Environ. Prot., 1: 13-16.

Zhao, Y., 2009. Thermal performance of heating system of hot-wall kang in northern rural areas. M.Sc. Thesis, Dalian University of Technology.

Zhou, Z., X. Wang, Q. Chen, S. Chen and W. Wu, 2007. Evolvement of well-off rural household energy consumption structure in northern China: A case study in huantai county of shangdong province. Trans. CSAE, 23: 192-197.

Zhu, M., 2011. China rural energy industry development proposals. Agric. Eng. Technol. Renewable Energy Ind., 8: 1-5.