A survey on the energy consumption in rural households in the fringes of Xian city

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Abstract

A survey, in the form of a questionnaire, of energy consumption patterns in rural residential households in the rural fringe of the Xian city was undertaken during the winter of 2003/2004. More than 200 households were sampled during the survey. Fuel consumption state, including biomass fuels for cooking and space heating, is investigated. The types of stoves, purpose of the stove use, and characteristics of the residential houses and residents were also reported.

The purpose of the survey was to clarify the status of energy consumption and to estimate emissions of greenhouse gases and air pollutants in rural areas of China, from the environmental perspective of climate change and indoor air pollution. In rural areas of China, biomass (such as stalks, corn canes and twigs, branchers of wood) is the type of fuel most commonly used. It emits several air pollutants: Particulate Matter (PM), CO, NMHCs, CH4 and high levels of Black Carbon (BC) , a greenhouse effect aerosol. From this survey it would then be possible to analyze the fundamentals of emission reduction potential, for air pollutants and greenhouse gases, from the rural household sector in China.

Key words: / Energy-Consumption, Greenhouse-Gas, Air-Pollutants, Household, Residential-House, Climate-Change, Rural, Xian, China /

1. Introduction

Residential energy consumption in rural areas of China is very interesting from several viewpoints, due to its impact on: climate change strategy, air pollution controls (especially indoor air quality), energy resource constraints and energy conservation, the household economy for farmers, social behavior and lifestyle changes - due to a move from traditional agricultural production to a market economy. Overall emissions are high due to the large population size but heat demand requirements can vary significantly due to: weather conditions; indoor thermal environmental levels; types of dwelling and lifestyle of the region. In previous studies we have analyzed residential household energy consumption, greenhouse gases and air pollutant emissions in China based on the energy statistics (separated by urban and rural area) of mainland China and regional variations by province[1)~5)] ,which are macro-approach studies. In contrast, this study uses a micro-approach by undertaking a case study in rural fringes of Xian city in the Shanxi Province.

A survey, in the form of a questionnaire, of energy consumption patterns in rural residential households in fringes of the Xian city was undertaken during the winter of 2003/2004. More than 200 households were sampled during the survey. Fuel consumption state, including biomass fuels for cooking and space heating, is investigated. The types of stoves, purpose of the stove use, and characteristics of the residential houses and residents were also reported.

Prof. Liu Jiaping, of the School of Architecture, Xi'an University of Architecture & Technology, who is a co-author of the paper, conducted the survey.

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it would then be possible to analyze the fundamentals of emission reduction potential, for air pollutants and greenhouse gases, from the rural household sector in China. The survey also helps to examine the details of the actual state of fuel consumption in rural households, as a background to the macro-level data.

2. Previous Studies

From our estimates, total energy consumption of rural residential households in China in 1999 is 8.3EJ (Exa=10^{18}), average per capita consumption in rural areas is 10.14GJ/year/capita and per household consumption is 43.11 GJ/year in 1999 -of which approximately 80% is biomass fuel,[2]. Total energy consumption of residential households in China is 10.7EJ, of which, 78% was from rural households[2),4)] . For the evaluation of countermeasures to climate change Hu X. and Jiang et al of the Energy Institute of China (2002) analyzed CO2 emissions from households in China in 1995 [6)], which was a typical macro-approach study of CO2 emission reduction potential.

In terms of rural and biomass energy consumption, Wang Xiaohua of Nanjing Agricultural University has undertaken studies using both macro and micro approaches[7),8)]. For example, his group surveyed 12 villages and 4 towns in Sheyang County in Jiansu Province and investigated data from 384 households. The results of our study are compared to this later on.

Smith K.,Sinton J. et al of LBL in California Barkley and Zhao Yaoyun et al of Renmin University of China have undertaken a questionnaire survey of energy consumption in rural households and its dose response to human health in three rural areas in China. The work has currently finished and a report is due to be published within a few years[9)]. We quoted the questionnaire from this study to pursue the possibility of a combined analysis.

3. Survey methodology

The original survey is designed to analyze the impact of indoor air quality on human health, due to air pollution from cooking stoves, and the effect of improved cooking stoves in rural households in China. The questionnaire consists of six sections including questions on health effects. Our study does not aim to analyze the health effects of indoor air quality itself, but rather to concentrate on the status of energy consumption, so the part on health effects was omitted. The items within the questionnaire are summarized in Table-1.There are items on household characteristics; size of household, income, vocation or occupation of the head of household. In terms of dwelling characteristics, materials of wall, roof, floor, and in detail about cooking room are investigated as well. Fuel use in stoves by fuel type is the key item, and there are many items on fuel type and stove type; main fuel type by end-use purpose and season, types of owing stoves, that of main use for cooking and space heating respectively, end-use purposes by stove type and so on.

Table-1 Items of the Questionnaire Sheet

Number of household members
Owning Goods
Income
Vocational Occupation
Dwelling Characteristics
Fuel Type by season and purpose
Fuel consumption
Owing Stove Types
Main Stove Type for Cooking
Main Stove Type for Space Heating
Perpose of Stove Use
Kang use
Other items(not analyzed in this paper)
Kitchen Characterristics
Ventilation
Cooking Practices
Stove Characteristics

Table-2 Fuel Type

1	Wood (logs)
2	Wood (twigs / branches)
3	Crop Residues
4 #	Dung Cakes
5	Coal/Coke/Lignite
6 #	Charcoal
7 #	Kerosene
8	Electricity
9	LPG(Liquid Petroleum Gas)
10 #	Biogas
11 #	Other (Specify)

#: Not appeared in this area

Table-3 Stove Type

1	Traditional Biomass
2	Improved Biomass
3	Coal Combustion
4	LPG
5 #	Biogas
6 #	Open Fire
7 #	Other(Specify)
In Separate Question	
*	Kang(Heated bed)
* #	Huoqiang(Hetaed Wall)

#: Not appeared in this area

In terms of fuel categories, 11 fuel types are stated in the questionnaire, as shown in Table-2, but only 6 of these types of fuel are actually used in this area. Seven stove types are also stated, as shown in Table-3, of which four types are used in this area. A separate question is used to investigate the installation of “kang (Heated bed)” and “Huoqiang (Heated wall)”. In the surveyed area many households have kangs but no huoqiang are used. Biomass stoves are categorized into two types, “Traditional” and “improved”.

Using the combination of installation of “kang”, four types of installations can be categorized. From the many possible combinations of end use and type of stove/fuel, the following combinations of stove and fuel types for space heating and cooking have been categorized and counted, as shown in Table-4.

Fuel consumption was the key focus of this study, but it was sometimes difficult to get the data required. For example, the units of fuel consumption vary on a case by case basis not consistently by kg per day or per month. The answers to questions on fuel consumption are all converted to kg in solid fuel cases, and to low

calorific heating value base units in Joules. In the case of biomass fuels, moisture is considered as follows: 30% for crop residues, 25% for wood logs or twigs, branches. The assumed calorific values are shown in Table-5.

The interviewers, students of the architectural school, visited the households in the sample area and spoke to family members about the items on the questionnaire. Within the selected survey area, a variety of villages were considered, from purely agricultural villages to those closer to towns and urban areas. Seven areas in two cities and two prefectures were selected for this survey. Table-6 shows the characteristics of the surveyed areas and numbers of sample households used in this analysis. In the seven areas the total number of households sampled was 218. Of these 60 were in non-agricultural areas, with many commercial workers, where coal and LPG are used in many households, however, kang is not used in these areas. The survey results are influenced by this component of the surveyed area.

Table-4 Type of stove and fuel used for cooking and space heating

	Main.Stoves and Fuels	Cooking		Space.Heating	
1	Crop.Residues-Kang・Traditional	110	50%	105	48%
2	Crop.Residues-Traditional.Stove	9	4%	5	2%
3	Crop.Residues-Kang・Improved	18	8%	17	8%
4	Crop.Residues-Improved.Stove	4	2%	0	0%
5	Twigs-Kang	2	1%	4	2%
6	Twigs-Traditional.Stove	5	2%	4	2%
7	Twigs-Kang・Improved	5	2%	7	3%
8	Twigs-Improved.Stove	0	0%	0	0%
9	Coal	35	16%	72	33%
10	LPG	30	14%	0	0%
11	Electricity / Unknown	0	0%	4	2%
	Total	218	100%	218	100%

Table-5 Low Calorific Value of Fuels

Fuel Types	Low Calorific Value	
Wood Logs	16726	kJ/kg
Wood Twigs/Branches	16726	kJ/kg
Crop Residues	14635	kJ/kg
Coal	20908	kJ/kg
LPG	50179	kJ/kg
Electricity(2nd Energy)	3596	kJ/kWh

4. Survey Results

4-1 Features of households

The average size of the surveyed households is 4.3 persons per household. Fig-1 shows the histogram of household size with a minimum of one person and a maximum of 8 persons per household. The most frequent size is four or five persons to one household. Fig-2 shows the histogram of income level in the surveyed area. Average income per household is 6100 RMB(Chinese-yen)/year. The vocation or occupation of the head of families is shown in Fig-3, and varies considerably, because this does not consist purely of agricultural occupations.

4-2 Stove Type

Fig-4 shows the results from the survey of the components of stoves within this area. A maximum of four stoves are used in one household. The average and highest frequency was two stoves. The number of owned stoves by stove type is shown in the second line in Fig-4. Coal is dominant stove-type in this figure but the dominant fuel type is biomass, as coal stoves are not used as the main type of stove in many households, as shown below in Fig-4.

The third and fourth lines show that stoves are used primarily for cooking and space heating. In this area the main stove type is kang, used for both cooking and space heating, and almost half of all main stoves are traditional kang using biomass fuels. The most typical type of stove is kang and the most typical fuel is crop residue, in some cases an improved type of kang is installed and in some cases the main fuel is twigs or branches of wood. Biomass cooking stoves without kang are also used and some of these are of an improved type, but their share in this area is not large. Coal stoves are used mainly for space heating in winter, but this is mainly in suburban areas and in this case kang is not installed. LPG stoves are also used for cooking but their level of penetration is low compared to other types. Even when LPG stoves are installed in agricultural areas the main fuel for cooking is still crop residues because the price of biomass fuel is zero and supply is abundant. But the level of LPG use is increasing, particularly as it penetrates to rural areas

Table-6 Characteristics of Surveyed Areas and Samples

Area	Samples	Featurs of the Area
1	43	Main Fuel is Crop Residues, Many have Kang, partly improved Kang. Is Tipical Agricultural Aaea
2	38	Main Fuel is Crop Residues,partly twigs used. Many have Kang, partly improved Kang. Is Tipical Agricultural Aaea
3	35	Main Fuel is Crop Residues,partly twigs used. Many have Kang, partly improved Kang. Is Tipical Agricultural Aaea
4	33	Main Fuel is Crop Residues,partly twigs used. Many have Kang, partly improved Kang. Is Tipical Agricultural Aaea
5	5	Main Fuel is Crop Residues. Many have Kang. Small Samples.
6	4	Not having Kang. Coal is used. Small Samples.
7#	60	Main Fuel is Coal, Many are Combination for Cooking LPG and for Space Heating Coal, Biomass Fuel use is rare. They don't have Kang. Is not Agricultural Aaea
Total	218	

: Area 7 is urbanized area different from any other rural areas.

from the fringes of urban areas, as can be seen in the area surveyed in this study.

4-3 Fuel Type

The main purpose of this survey is to analyze the status of fuel consumption in rural areas. However, it is difficult to accurately measure the level of fuel consumption. Consumption of solid fuels were answered in the questionnaire on a weight base, either per kg per month or per day and converted to a low calorific value base as mentioned above. In this survey 218 samples were obtained but some of these had incomplete fuel consumption data. The survey was undertaken in winter and therefore the reported levels of fuel consumption are possibly higher than the annual average. The consumption level per household or per capita is analyzed later on, but it is currently still difficult to estimate the annual energy consumption by converting results of the survey. Fuel use components are influenced by the conversion estimates, any figures that are not shown in his paper, will hopefully be presented at the meeting.

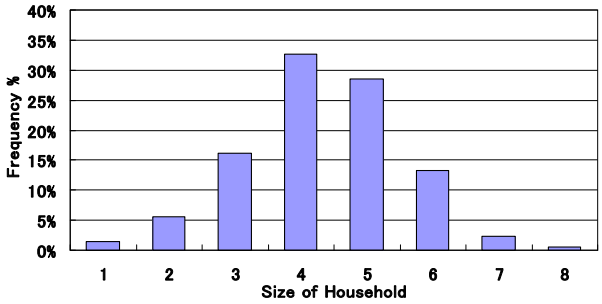

Fig-1 Household Size in the Surveyed Area
n=218 Average=4.3persons/household

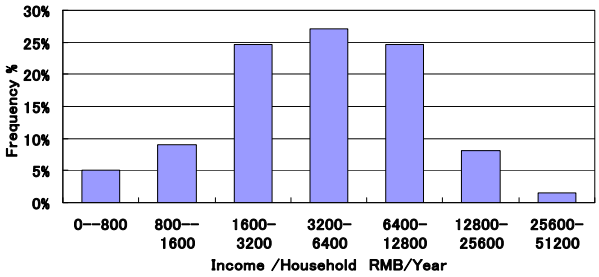

Fig -2 Income Rank per Household
n=199

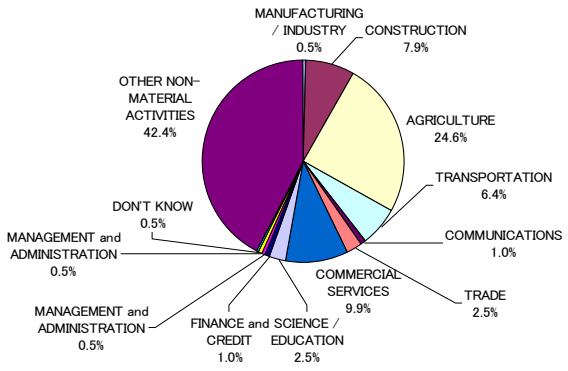

Fig-3 Vocational Occupation in the Surveyed Area

4-4 Purpose of Stove Use

In this survey the purpose of stove use was also investigated. Fig-5 shows end-use by stove type. This is not based upon fuel consumption but the frequency of answered questions. Biomass stoves are used for cooking, tea making and boiling water, and in some cases are also used to heat animal feed. The share by purpose for coal is similar to biomass but there is a slightly higher share of space heating. LPG is used primarily for cooking and tea making and very little is used for other purposes. In many cases "Kang" are used. In this figure the percentage of space heating is small, but "kang" can also be used for space heating.

4-5 Appliance Use

In this study electricity use of appliances has not been surveyed, therefore it is not clear where, how and to what extent it is used in rural areas. The only data from the survey is based upon ownership of appliances, and is shown in Fig-6. TVs is owned in 86% of households. Washing machines and radios in 38%, refrigerators in 11% and personal computers in only 3%, but these appliances will penetrate rapidly into rural areas in the near future.

4-6 Correlation with Income Level

There are many factors determining energy consumption in rural areas, but as a first step the correlation with income level is examined. Fig-7 shows the correlation between income per household and energy consumption as the input base. The determinant factor is 0.03, which indicates no correlation. Secondary correlation between income per capita and effective energy consumption per capita is also examined, but the result is the same with no overall correlation, as shown in Fig-8. From these results we can conclude that in rural areas energy consumption in households appears to show no correlation with income level.

However, when this is examined in more detail, for example LPG consumption (which is an expensive form of commercial energy for rural areas), then this would have a more explicit relationship with income level. From this hypothesis the average income level categorized by LPG consumption state is estimated, and is shown in Fig-9. The households which used LPG as the main cooking fuel showed the highest income levels, and as LPG use for cooking became the second, third and fourth most utilized type of fuel the level of income amongst these groups, dropped correspondingly. This is the general the case for the suburban areas which were also included in the survey area, rather than in the purely agricultural areas, but a clear relationship between income level and LPG use is observed.

5. Comparison with other surveys

As mentioned above in the introduction, we estimated the fuel consumption in rural areas by province in 1999. We can then compare the survey's

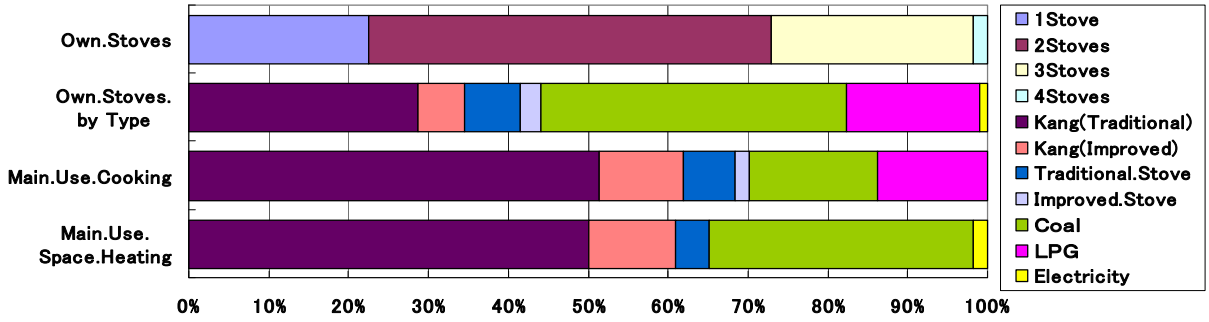

Fig-4 Components of Stove Type within the Surveyed Area

Stoves.Owned : Numbers of households owning one to four stoves.
Stoves.Owned.by Type : Numbers of stoves owned in the area
Main.Use.Cooking : Number of households for which the main use of stove type is cooking
Main.Use.Sapce.Heating : Number of households for which the main use of stove type is space heating

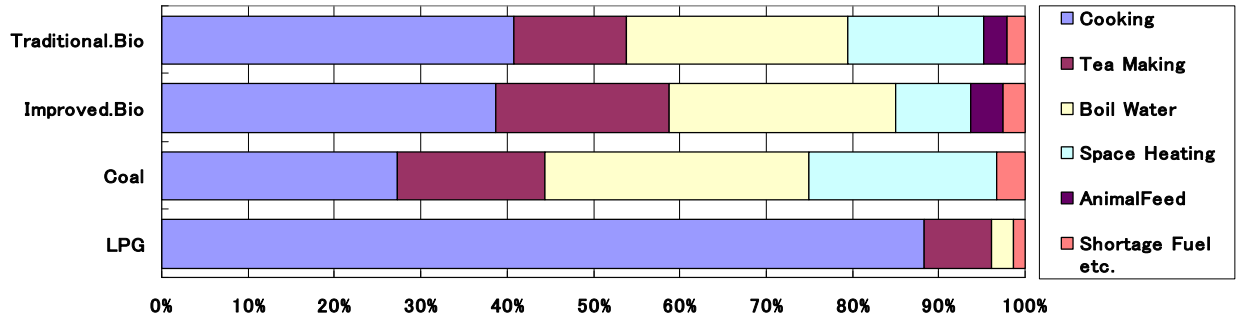

Fig-5 Purpose of Use by Stove Type

results in rural fringes of the Xian area with the average for the Shanxi province. In the "China Energy Statistical Yearbook", household energy consumption is reported separately by two sectors: urban areas and rural areas - including biomass fuels. Using this, energy consumption in rural area households can be estimated by province[2]. The average of the Shanxi province is 30.6 GJ/year/household in 1999, and the average of this survey is 74.3GJ/year/household. The result of this survey is over two times larger than the provincial average, but it might be overestimated because the survey was undertaken during winter.

We have estimated annual fuel consumption from monthly consumption in winter, but in many cases crop residues are used for kang which cannot be separated into consumption for cooking and space heating, and this is the main possible cause of an overestimation.

Wang Xiaohua undertook a similar survey in Sheyang County in the Jiansu province in 1997[7]. The area is further south than the Xian area, and so the space heating load is smaller. But it is also a more developed area, so electricity demand is much higher than in the Xian survey area. From the 384 samples, from 12 villages and 4 towns in Sheyang, the average energy consumption was 8.6GJ per capita in 1997, which is almost at the same level as the 8.8 GJ/ capita in Shanxi province in 1999. In the case of Sheyang, less than 5% is used for space heating (much lower than for the Xian area), 71% is used for cooking, 8% for water heating and 5% for pig feed heating.

Of this, a total of 84% is used for cooking and water heating. 11% is used for lighting, including appliance use. By fuel type, 72% is biomass, of which Straw is 56%, Firewood 14% and 2% is biogas. Coal comprises 10%, LPG 6% and electricity 11%. The share of components is slightly different but for both areas the dominant source is biomass, primarily crop residues. Electricity and LPG use has a higher penetration than in the Xian survey area. 17.2 GJ/capita from the average of this survey may probably be too large when compared to the Sheyang survey and the average of statistical data in the Shanxi province.

The level of annual fuel consumption from the survey data might be currently an over-estimate. This over-estimate will hopefully be modified for the presentation at the meeting.

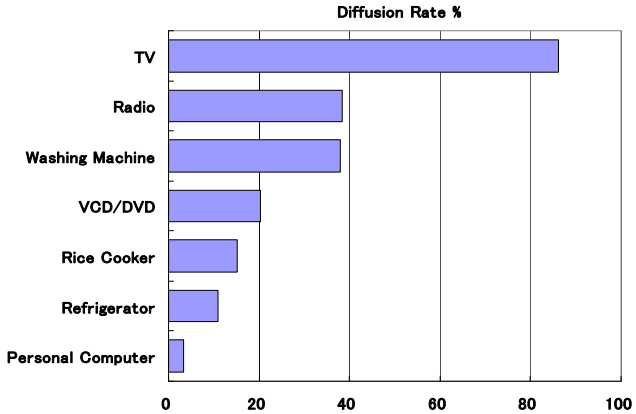

Fig-6 Appliance Diffusion Rate in the Surveyed Area

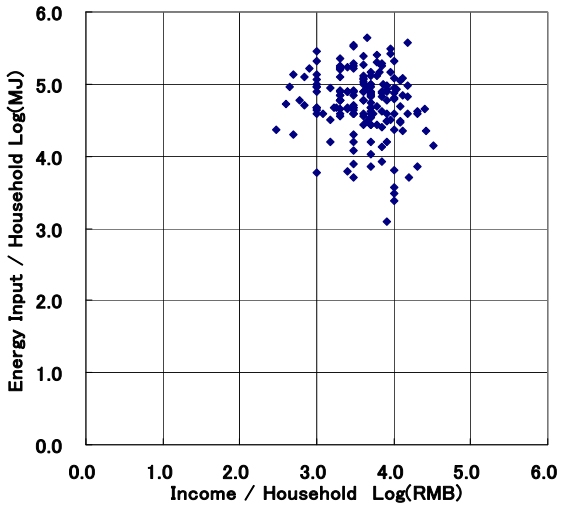

Fig-7 Correlation between Income level and Energy Consumption per household R^2=0.03

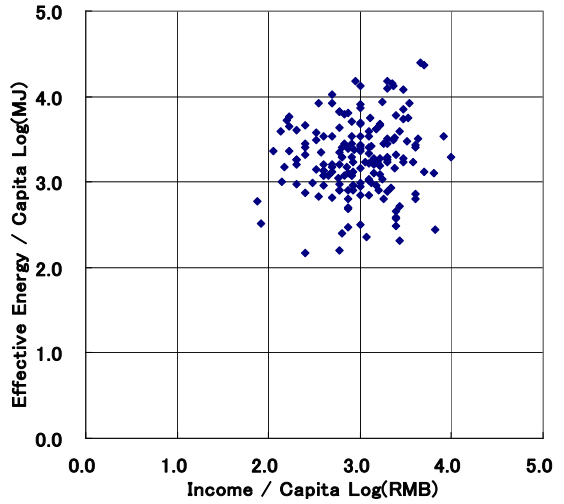

Fig-8 Correlation beween Income per Capita and Effective Energy per Capita R^2=0.01

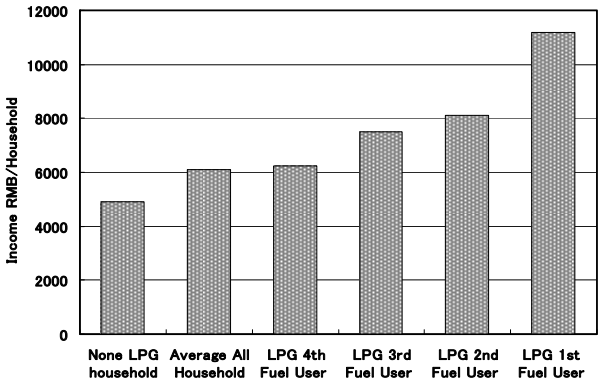

Fig-9 LPG Use and Income Level

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