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Energy Poverty and Solid Fuels Use in Rural China: Analysis Based on National Population Census

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Abstract: China has basically achieved ubiquity of electricity access in rural areas during the latest three decades. However, solid fuels are still widely used in the rural areas, which is currently the main issue impinging upon energy poverty in China. There about 490 million rural residents in China using solid fuels for cooking. Based on national population census data, this research evaluates the current situation and long-term trend of solid fuel use for cooking in rural China. Firstly, over three-fourths of all rural households depend on solid fuels to meet their cooking demand, whilst in urban area and township this figure is as low as 8 % and 36 % respectively. Secondly, solid fuel use was linked closely to rural household income, i.e., those regions with low *per capita* household income use more solid fuel. Furthermore, rural households using solid fuel declined by 17 percent from 2000 to 2010, albeit with some significant regional differences. Finally, the proportion of rural residents using clean fuels remained low, and the proportion using gas remained nearly constant over last 10 years in many provinces. Improving access to affordable and reliable energy services for cooking remains a great challenge China need to address.

Keywords: Energy Poverty; Solid Fuels; Cooking; Population Census; Rural Households; China

1 Introduction

The level, structure and potential for residential energy consumption are regarded as crucial indices reflecting the economic and social development. The International Energy Agency (IEA) pointed out that populations suffering energy poverty were mainly characterised by the inaccessibility and unavailability of electricity or clean cooking facilities, as well as their dependency on traditional biomasses and other solid fuels for cooking: nearly 1.3 billion people did not have access to electricity, and more than 2.6 billion people relied on the traditional biomass for cooking in 2011. Moreover, about 2.5 billion worldwide will still lack clean cooking facilities in 2030 [1-3].

Energy poverty is also one of the major challenges faced by countries around the world, especially those developing countries [4-7]. Cooking and heating with solid fuels on open fires or stoves without chimneys leads to indoor air pollution, which has negative impacts on both people's health, the environment and climate change [7-13]. In addition, biomass (e.g., wood, animal dung) collecting consumes considerable time for women and children, limiting other productive activities and causing a bad impact on children's learning [14-19]. On the whole, energy poverty and related problems restrain the sustainable development of economy and environment [1, 16, 19-21].

The United Nations (UN), World Health Organization (WHO), World Bank, International Energy Agency (IEA), and other international organizations have been concerned with these issues and are seeking countermeasures [22-24]. In 2011, under the leadership of UN Secretary-General Ban Ki-moon, a coordination team composed of 20 UN agencies proposed a global initiative, Sustainable Energy for All. The initiative would improve energy efficiency, promote the development of renewable energy and universal energy access by 2030.

China has basically completed the transformation of its rural power grid. According to "A 3-year action plan (2013 to 2015) for comprehensively solving the problems of electricity-use in non-electrified areas", it

was expected that the electricity-use problems of the remaining 2.73 million people in non-electrified areas could be resolved by 2015 [25]. However, using electricity for cooking puts high capacity demands on electric grids and is often a bad thing, especially when cooking load is a major fraction of total electricity load. Hence, combining various modern cooking fuels may be a feasible way to reduce the burden of electric systems.

The population in energy poverty in China is mainly composed of rural residents using traditional solid fuels such as biomasses (mainly firewood) and coal. Based on population census data, it was deduced that there were approximately 490 million rural residents and 170 million urban residents using coal or biomass for cooking in China in 2010. Therefore, the use of solid fuel was the main reason for rural areas in China are hard-hit by indoor air pollution. Meanwhile, the use of solid fuels impaired the health of rural residents in China [26-27].

It is commonly known that another major cause of indoor air pollution is the use of traditional stove (without a chimney or grate). In 1983, The Ministry of Agriculture (MOA) initiated the National Improved Stove Program (NISP) to deliver clean and efficient stoves to the rural households in China. Based on the currently available data published by the Ministry of Agriculture (MOA) and National Bureau of Statistics (NBS), 59.2% of rural households in China had improved stoves in 2007 [28-29]. However, Sinton et al. [30] found that the official data may overestimate the number. Hence, the real figure is probably much lower. In addition, Hanna et al. [31] pointed out that the improved stoves were usually used in an inappropriate way, so the quality of indoor air was not improved.

Therefore, the indoor air pollution remains a problem for rural households, even for those using the improved stove, in China. The most recent Global Burden of Disease (GBD) project [32] estimated that approximately 1.04 million residents die prematurely as an indirect result of solid fuel-induced indoor air pollution in China. These deaths accounts for 12.5 % of all premature deaths and are equivalent to the number of premature deaths triggered by atmospheric particulate matter (1.23 million). This result showed

that China (especially in rural areas) still faces severe energy poverty and the health problems induced thereby. Moreover, it exerts significant negative influences on the long-term well-being of rural residents, especially with regard to children's education and health [33-35].

China's energy poverty and related issues has attracted the attention from domestic and abroad. Sinton et al. [30] have conducted an assessment of programs to promote improved household stoves in China. Peabody et al. [36] and Edwards et al. [37] studied the negative impact of cooking fuels and stoves on health. Zhang and Smith [27] provide a survey of the literature on the relationship between indoor air pollution and health. However, most of these researches merely relate to certain local areas in China [38-39].

In addition, Li et al. [40] employed the regular statistical data and one year agricultural census document for evaluated energy poverty situation in China. Here, we further investigate this issue from more perspectives and based on a more detail dataset. First, we use two national population census dataset (Year 2000 and 2010), and 1% national population sampling dataset (Year 2005). The national population census covers all the households in Mainland China. Second, we discuss the differences in household energy structure for cooking between the urban and rural. Meanwhile, we analyze the changes in household cooking energy in a dynamic way, which is also one of our main contributions. Another contribution in this paper is that we pointed out the imbalance development across China based on the provincial analysis, since it is known that the policies addressing energy poverty should be region- or province-specific. Finally, we quantitatively discussed the relationship between income and solid fuel use in the rural areas for different years.

Based on China's national population census data in 2000 and 2010, as well as the 1 % population sample survey data in 2005, this research analysed the current situation and long-term trend in solid fuels use for rural household cooking in China. China's population census calls for 10 % of households to complete the "Long table", which contains questions about housing facilities, such as choice of cooking fuels. In

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addition, we also analyzed the long term trend of the use of clean fuels in China's rural households.

2 Differences of household energy structure for cooking between urban and rural areas

Based on the population census data in 2010, the energy use associated with cooking differed depending upon whether a household was urban or rural. As shown in Figure 1, more than 75 % of rural households mainly use solid fuels for cooking, including 17.1 % and 58.6 % with coal and biomass as their primary cooking fuels, respectively. However, only 8.2 % and 36.1 % of households in urban and township areas used solid fuels for cooking, respectively. Moreover, 90.3 % of urban households chose clean fuels (*i.e.*, gas or electricity) as their primary cooking fuel. The proportion of urban households depending on gas reached 80.7 %. The households using clean fuels also accounted for 62.7 % of the total townships, while the proportion was only 23.2 % for rural areas.

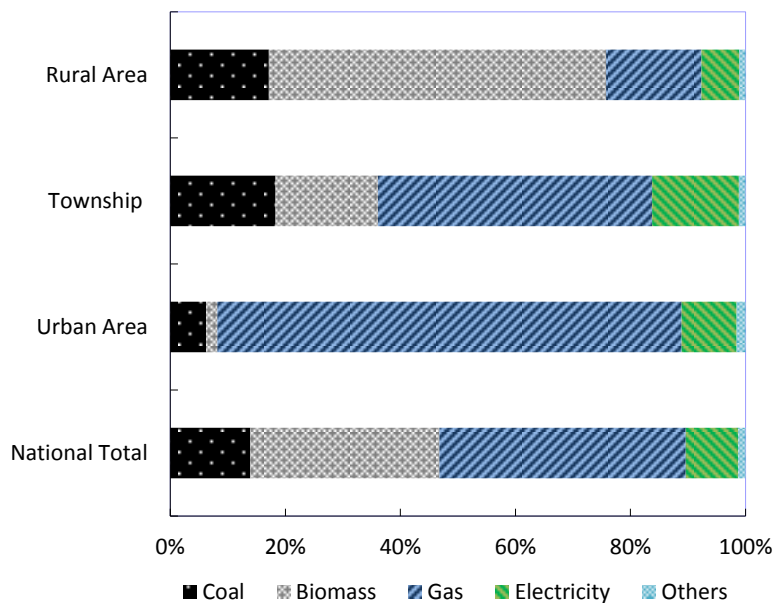Figure 1. Primary household cooking energy in urban, township, and rural areas in 2010

Data source: China's Sixth National Population Census in 2010.

Notes: In the census, the geographic regions of China are divided into towns and villages: the former include cities and townships, while the latter are referred to rural areas in this research. Gas includes mainly coal gas, natural gas and liquefied petroleum gas.

3 Spatial differences of rural household energy structure for cooking

Attributed to the discrepancies in available resources and the level of economic development in each province, the rural energy consumption in cooking differed across China. As shown in Figure 2, many rural households use coal in Shanxi, Henan, and Guizhou (60.0 %, 35.1 % and 34.7 %), each of which is endowed with rich coal resources. Moreover, in less-developed provinces such as Ningxia, Xinjiang, Gansu, there are also a large number of rural households relying on coal. In addition, a large number of rural households use biomass as the primary cooking fuel. In particular, in Northeastern China (e.g., Liaoning, Jilin, and Heilongjiang) where there are rich forest resources, nearly 90% of rural households mainly rely on biomass for cooking. In contrast, in eastern developed provinces, more than half the rural households mainly use clean fuels.
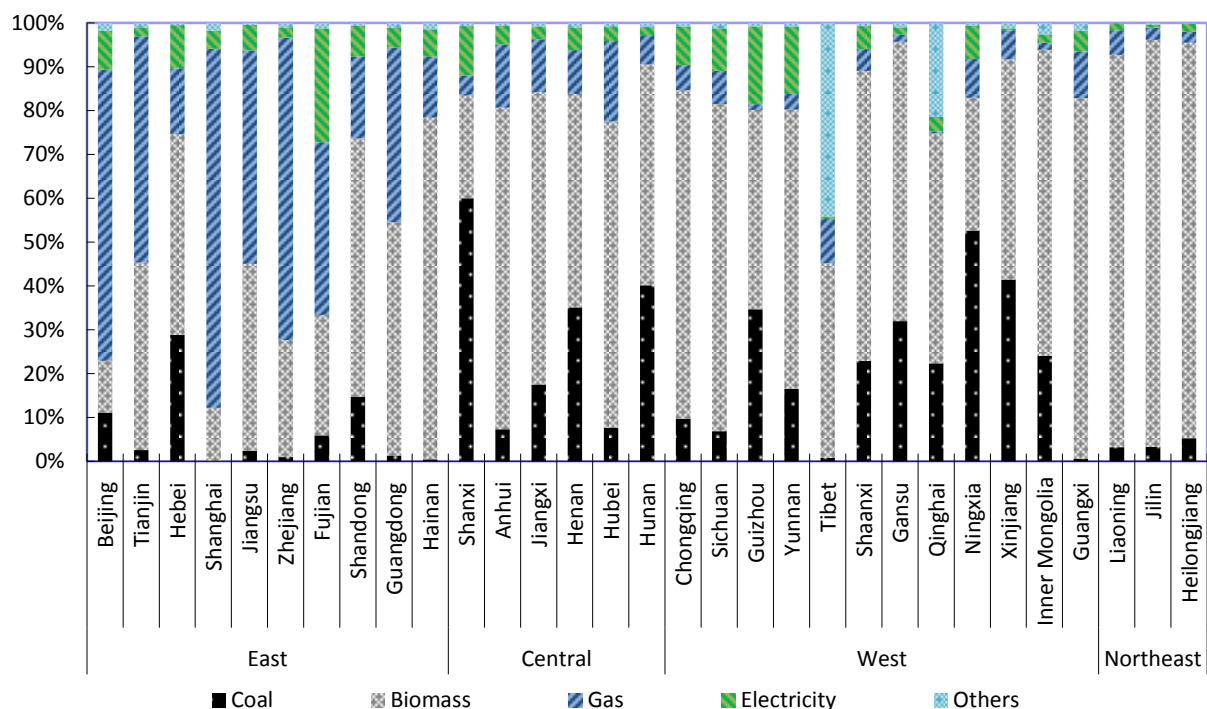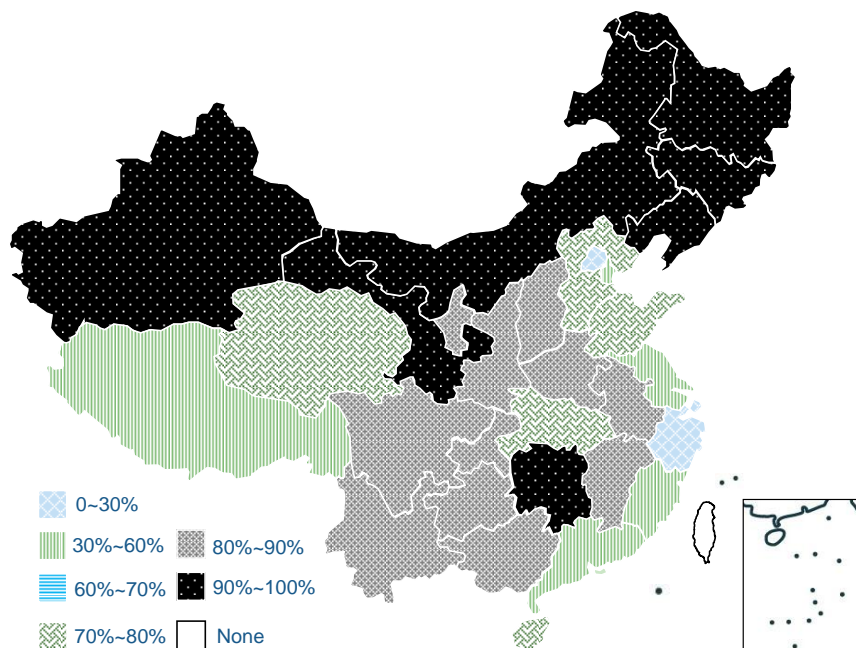

Figure 2. Rural households' primary cooking fuel use, by province in 2010

Data source: China's Sixth National Population Census in 2010.

The distribution of rural and urban households mainly using solid fuels for cooking in China is plotted in

Figure 3, where the spatial differences in solid fuel use are shown.

It can be seen that the rural households in eastern China, *e.g*. Shanghai, had the least dependence on solid fuels. Merely 12.2% of rural households chose solid fuels as their primary cooking fuel. As *per* the analysis above, in northeast China, including Jilin, Liaoning and Heilongjiang, there were approximately 90 % of rural households that mainly relied on biomass. In addition, there were also a considerable number of rural households depending on solid fuels for cooking in Henan in Central China, and Yunnan and Guizhou *etc*. in western China. The distributing characteristics of urban and township households using solid fuel are similar to those of rural households. Tibet is special provincial region in Mainland China except for its status of low economic development: (1) Tibet has smallest population in all provinces. (2) Tibet is rich in solar, wind, geothermal and hydro energy sources, and it has hardly no coal resource. (3) Though Tibet's economic output is small, it has received many economic aid from the central government. (4) Due to the low temperature, many resident firstly use solid fuels for heating not cooking. (5) Our census data only collect the data of cooking fuel that "mainly" used. It is possible that many Tibet resident usually (but not mainly) use solid fuel for cooking.

a. Rural area
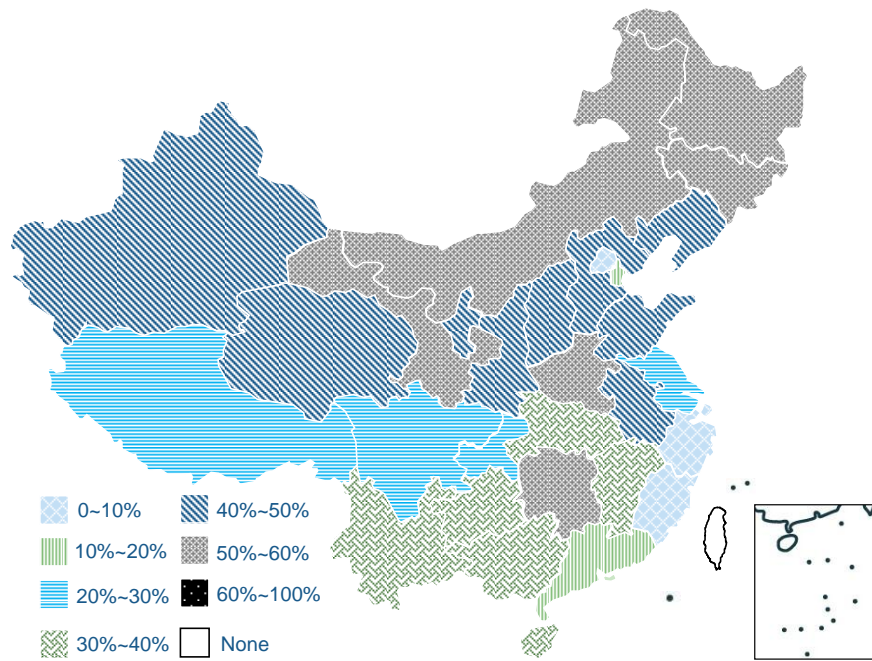
b. Township
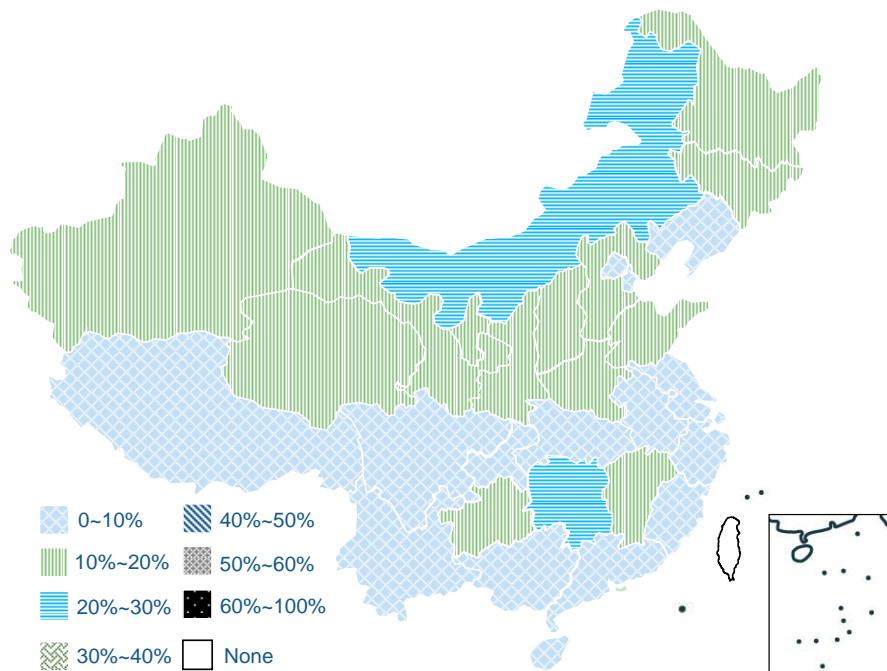
c. Urban area

Figure 3. Distribution of households using solid fuels as primary cooking fuel in 2010

Data source: China's Sixth National Population Census in 2010.

Notes: Solid fuels mainly included: coal and biomass. Data from Hong Kong, Macao and Taiwan were excluded. It is a schematic map and does not implicate the definite boundaries.

4 Correlation of cooking fuel use with household income

From 2000 to 2010, with increasing rural household incomes, an increasing number of rural households substituted solid fuels with cleans fuels for cooking, or used clean and solid fuels alternately. Meanwhile, the proportion of rural households relying on solid fuels showed a decreasing trend. The energy-using ability of rural residents was greatly determined by income. As shown in Figure 4, the regions with low *per capita* income presented higher solid fuel use. In contrast, those with high *per capita* incomes exhibited low solid fuel use. In addition, we have applied one-dimensional linear regression to study the relationship between household solid fuel use and income. The ordinary least squares (OLS) regression line for year 2010 or 2005 presented higher income levels and greater variability than that for 2000, suggesting that compared with 2000, rural residential incomes saw significant growth in 2010. Moreover, the imbalance in solid fuel use in rural areas continued in 2010.
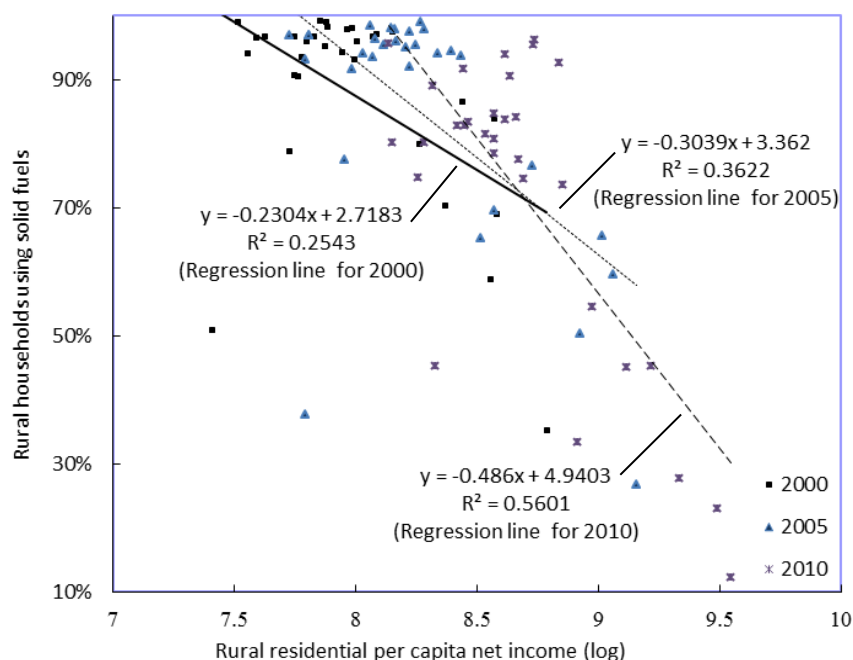

Figure 4. The correlation of rural households using solid fuels with their *per capita* net income

Data source: China's Fifth and Sixth National Population Census (2000 and 2010), China's National 1 %

Notes: The data are composed 31 provinces in China, except for Hong Kong, Macao and Taiwan. The proportion of rural households using solid fuels was obtained from census data, while the rural *per capita* net income was real income that was calculated by rural residential consumption price index on the base period of 2010 and the rural residential nominal *per capita* net income year of each area.

5 Gradually reducing trend and significant regional differences in rural solid fuel use fro 2000 to 2010

The use of solid fuels in rural China shows a gradually reducing trend and significantly long-term regional variations, as listed in Table 1. In 2000, the proportion of rural households that mainly used solid fuel for cooking reached 92.8 % nationwide. In 2010, this proportion fell to 75.8 %: an average annual reduction of approximately 1.7 percentage point. On the whole, this proportion saw large reductions in the eastern developed areas, while exhibiting insignificant variations in the mid-western areas. During 2000 to 2010, the proportion of rural households relying on solid fuel for cooking decreased significantly in developed areas such as Zhejiang, Fujian, Beijing, Shanghai; in Beijing, this proportion decreased from 69.1 % in 2000 to 22.9 % in 2010. However, in developing areas, such as Ningxia, Gansu, Xinjiang and Inner Mongolia, the proportion only decreased slightly: in Inner Mongolia, it fell from 94.3 % in 2000 to 93.9 % in 2010.

Table 1. Changes of rural households using solid fuel from 2000 to 2010, by province

Province/Region	Year 2000		Year 2005		Year 2010	
	Number/10^3	Percentage	Number/10^3	Percentage	Number/10^3	Percentage
Total	19,137	92.8	2,567	90.4	14,623	75.8
East	5,629	85.2	690	78.7	3,420	55.9
Beijing	60	69.1	7	59.6	20	22.9
Tianjin	65	84.0	7	65.6	36	45.3
Hebei	1277	97.1	161	94.1	854	74.6
Shanghai	22	35.2	2	26.8	11	12.2
Jiangsu	1043	86.5	114	76.5	447	45.1
Zhejiang	439	58.9	51	50.3	210	27.7
Fujian	389	79.9	48	65.2	154	33.3

Shandong	1651	97.6	207	93.8	1147	73.6
Guangdong	591	70.4	81	69.5	454	54.5
Hainan	92	93.2	11	92.0	86	78.4
Central	6138	97.5	844	96.5	4674	83.6
Shanxi	541	99.2	70	97.9	439	83.5
Anhui	1116	96.1	151	94.2	795	80.7
Jiangxi	656	95.2	101	95.4	534	84.2
Henan	1804	99.0	236	98.0	1351	83.8
Hubei	825	96.1	126	95.1	633	77.5
Hunan	1197	98.1	160	97.6	922	90.5
West	6041	94.9	852	94.7	5246	84.2
Chongqing	544	96.8	68	96.4	377	84.7
Sichuan	1588	96.8	237	95.5	1354	81.5
Guizhou	662	99.1	98	97.0	537	80.1
Yunnan	740	94.1	98	93.1	616	80.2
Tibet	20	51.0	2	37.7	21	45.2
Shaanxi	595	96.6	82	97.0	516	89.1
Gansu	416	96.9	58	97.0	428	95.7
Qinghai	56	78.8	8	77.6	54	74.8
Ningxia	80	93.6	11	98.5	73	82.9
Xinjiang	278	90.8	40	93.6	290	91.7
Inner Mongolia	349	94.3	43	96.0	321	93.9
Guangxi	711	90.5	108	91.8	660	82.8
Northeast	1329	97.6	181	96.9	1283	94.6
Liaoning	535	96.8	67	94.5	485	92.7
Jilin	348	98.3	50	99.1	342	96.1
Heilongjiang	446	98.0	64	97.8	455	95.5

Data source: China's Fifth and Sixth National Population Census (2000 and 2010), China's National 1 % Population Sample Survey (2005)

Notes: Solid fuels included coal and biomass. In 2000, 2005, and 2010, a total of 20,628,301, 2,838,210, and 19,299,627 rural households were involved in the study, respectively.

6 Low uptake and slow growth of clean fuels in rural China from 2000 to 2010

The proportion of rural households relying on electricity or gas for cooking remained low in 2010, as shown in Table 2 and Table 3. As incomes increased, the sources of energy used for cooking were gradually diversified. However, since clean fuels are relatively expensive, while biomass resources are accessible

through non-commercial means in rural areas, the uptake of clean fuels remains low [41]. The clean fuels used by rural residents mainly included gas and electricity in 2010, and the number of rural households using gas and electricity for cooking differed significantly.

At present, electricity is basically ubiquitous in China after the transformation of its rural power grid. However, the use of electricity in rural China remained low, as listed in Table 2. In Fujian, Guizhou, and Yunnan, the proportion of electricity-using households showed a sustained increase from 2000 to 2010; however, there were only 26.0 %, 17.7 %, and 15.4 % of rural households using electricity, respectively. Nationwide, those households only accounted for 0.3 % in 2000 (60,000 households) and 6.6 % in 2010, with an annual increase rate of 0.6 percentage points. In addition, the proportion of electricity-using rural households in Jilin, Xinjiang, *etc*. had not exceeded 1 % by 2010.

Table 2. Changes of rural households using electricity from 2000 to 2010, by province

Province/Region	Year 2000		Year 2005		Year 2010	
	Number/10^3	Percentage	Number/10^3	Percentage	Number/10^3	Percentage
Total	62	0.3	16	0.6	1276	6.6
East	8	0.1	5	0.6	477	7.8
Beijing	0	0.1	0	0.3	8	8.8
Tianjin	0	0.0	0	0.2	2	2.1
Hebei	1	0.1	0	0.2	113	9.9
Shanghai	0	0.6	0	0.9	4	4.2
Jiangsu	1	0.1	1	0.4	58	5.8
Zhejiang	1	0.2	0	0.4	18	2.4
Fujian	1	0.3	2	2.9	120	26.0
Shandong	1	0.1	1	0.2	110	7.1
Guangdong	2	0.3	1	0.7	38	4.6
Hainan	0	0.2	0	0.6	7	6.2
Central	6	0.1	2	0.3	249	4.5
Shanxi	1	0.1	0	0.3	59	11.2
Anhui	1	0.0	0	0.3	42	4.2
Jiangxi	1	0.1	0	0.4	19	3.0
Henan	1	0.1	0	0.2	83	5.1
Hubei	1	0.1	1	0.4	26	3.2
Hunan	2	0.2	0	0.2	21	2.0
West	45	0.7	8	0.9	530	8.5
Chongqing	4	0.7	1	1.2	39	8.8

Province/Region						
Sichuan	16	1.0	3	1.4	161	9.7
Guizhou	2	0.3	1	1.0	119	17.7
Yunnan	17	2.1	2	1.8	118	15.4
Tibet	0	0.8	0	0.1	0	0.6
Shaanxi	1	0.1	0	0.3	30	5.2
Gansu	1	0.2	0	0.3	8	1.7
Qinghai	0	0.6	0	0.8	2	3.3
Ningxia	0	0.2	0	0.3	7	7.7
Xinjiang	0	0.1	0	0.2	1	0.4
Inner Mongolia	0	0.1	0	0.2	6	1.8
Guangxi	4	0.5	0	0.4	38	4.8
Northeast	2	0.1	1	0.3	20	1.4
Liaoning	0	0.1	0	0.2	8	1.6
Jilin	0	0.1	0	0.1	3	0.7
Heilongjiang	1	0.2	0	0.5	9	1.9

Data source: China's Fifth and Sixth National Population Census (2000 and 2010), China's National 1 %

Population Sample Survey (2005)

Owing to the construction of natural gas pipe network infrastructure in recent years, gas use has increased in rural areas in China. As indicated by Table 3, the proportion of rural households that used gas as their primary cooking fuel increased by 50 % in Beijing, Shanghai, Tianjin, and Jiangsu in 2010. However, on a national level, the proportion of rural households using gas for cooking was merely 16.5 % in 2010, which was still considered as being low. From 2000 to 2010, this proportion slowly increased by only 1 percentage point annually on average. Moreover, the proportion remained nearly constant over these 10 years for many provinces, such as Qinghai, Gansu and Guizhou.

Table 3. Changes of rural households using gas from 2000 to 2010, by province

Province/Region	Year 2000		Year 2005		Year 2010	
	Number/10^3	Percentage	Number/10^3	Percentage	Number/10^3	Percentage
Total	1,291	6.3	228	8.0	3,193	16.5
East	947	14.3	176	20.1	2,175	35.5
Beijing	26	30.4	4	39.3	58	66.4
Tianjin	12	15.6	4	33.2	41	51.6
Hebei	36	2.7	9	5.4	173	15.1
Shanghai	39	63.2	7	70.9	76	81.9
Jiangsu	158	13.1	34	22.8	483	48.7
Zhejiang	301	40.4	49	48.8	523	69.0

Fujian	93	19.1	22	30.0	182	39.5
Shandong	36	2.1	13	5.7	292	18.7
Guangdong	239	28.5	33	28.4	332	39.9
Hainan	6	6.3	1	6.4	15	13.9
Central	137	2.2	24	2.8	619	11.1
Shanxi	3	0.6	1	1.2	24	4.5
Anhui	42	3.7	8	5.2	142	14.4
Jiangxi	30	4.3	4	3.5	77	12.1
Henan	14	0.8	3	1.4	161	10.0
Hubei	29	3.4	5	4.0	150	18.3
Hunan	18	1.5	3	1.7	66	6.5
West	177	2.8	23	2.6	347	5.6
Chongqing	12	2.2	1	2.1	25	5.7
Sichuan	25	1.5	5	1.9	126	7.6
Guizhou	3	0.5	2	1.8	9	1.4
Yunnan	25	3.2	4	3.7	27	3.5
Tibet	1	3.6	0	1.7	5	10.1
Shaanxi	16	2.6	2	2.0	29	4.9
Gansu	4	0.9	1	1.1	7	1.6
Qinghai	1	1.8	0	1.0	0	0.4
Ningxia	5	5.6	0	1.0	8	8.8
Xinjiang	22	7.3	2	5.3	21	6.6
Inner Mongolia	2	0.6	0	0.5	6	1.6
Guangxi	59	7.5	6	5.0	85	10.7
Northeast	29	2.2	5	2.7	51	3.8
Liaoning	17	3.1	4	5.2	30	5.7
Jilin	5	1.3	0	0.7	10	2.7
Heilongjiang	8	1.7	1	1.6	12	2.5

Data source: China's Fifth and Sixth National Population Census (2000 and 2010), China's National 1 %

Population Sample Survey (2005)

6 Conclusions

Despite the popularity of electricity in China, energy poverty is still dominant in rural area. The dependence of rural residents on solid fuels remained relatively high albeit with evidence of some decreases. From 2000 to 2010, the proportion of rural households that used solid fuels for cooking was reduced by an annual rate of 0.7% nationwide: in 2010, the proportion was still above 75 %. In addition, the use of solid fuels by rural households presented significant regional differences across China. In the northeast, central

and the less-developed provinces, most rural residents still used biomass and coal as their primary cooking fuel. The highest proportion was found in Jilin and Gansu Provinces, as high as 96%. However, in the developed areas, there were a considerable number of rural households mainly using gas and electricity for cooking, especially in Beijing and Shanghai.

Statistical data also showed that the household energy structure was different between rural and urban areas, and urban households' dependence on solid fuels is very small. Over three-fourths of all rural households depend on solid fuels to meet their cooking demand, whilst in urban area and township this figure is as low as 8 % and 36 % respectively. In rural areas, the choice of cooking energy is mainly determined by income level as well as the prices of modern fuels. Restricted by the affordability of energy resources, amongst China's rural households, the proportion using clean fuel rose slowly from an initially low level. Nationwide, rural households rely on electricity for cooking only accounted for 0.3 % in 2000 and 6.6 % in 2010, with an annual increase rate of 0.6 percentage point. Likewise, in 2010, only about 17 % of rural households using gas as primary cooking energy.

From the above analysis, it is shown that rural households in China still depend to a large extent on solid fuels (mainly include biomass and coal) for cooking. Improving access to affordable and reliable energy services for cooking remains a great challenge China need to address. To overcome energy poverty and alleviate its negative impacts on people's health in rural China, some effective measures must be taken to solve this issue. For example, we can take appropriate measures to boost the infrastructure of clean energy supply, including solar power installation, natural gas pipe network facilities and clean cooking stoves, and so on.

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