Factors influencing the adoption and sustainable use of clean fuels and cookstoves in China -a Chinese literature review

Report to the program "review of Chinese evidence on adoption of clean cookstoves and fuels (RFP 13-1)" sponsored by Global Alliance of Clean Cookstoves (GACC)

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Jan. 15th, 2014

Abstract

Residential solid fuel combustion using fuels like crop straw, firewood and coal, usually has low efficiencies, and yields a variety of incomplete pollutants which significantly affect the local/regional air quality, human health, climate change directly or indirectly. The adoption of cleaner fuels and cookstoves is expected to achieve great benefits in many aspects. Among many deployment programs so far, some of them resulted in great success but some not. As such, it is necessary to identify key factors affecting the adoption and sustainable use of cleaner fuels and cookstoves, so as to offer a reference in future deployment program.

The research group headed by Dr. Pozzolo conducted a systematic literature research work on this. However, in their study, peer-reviewed literatures in Chinese were not included, although some studies conducted in China and reported in English publications were analyzed. Consequently, Global Alliance of Clean Cookstoves (GACC) supports a study to find evidence in Chinese peer-reviewed literature on the key enablers and barriers influencing the deployment and sustainable use of cleaner fuels and cookstoves (the main objective of the present study). We followed the research method by Pozzolo *et al.,* with only a small modification of some key words in the translation from English to Chinese so as to coincide with the Chinese word feature. A total of 47132 papers were found and 930 ones were selected in the first review for the read and analysis of abstract and keywords. In the second round, 351 papers selected from these 930 papers were read in full text, and finally, a total of 87 peer-reviewed papers were in-depth reviewed and analyzed after data extraction.

Based on these peer-reviewed Chinese literatures, it can be concluded that many subjective and objective factors affect the adoption and sustainable use of cleaner fuels and cookstoves. These factors include:

1) Fuel/stove technology. The burning and thermal efficiency, continuous supply, convenience and cost are critical factors affecting fuel adoption. For low income household, the cost of fuel is of prior concern, while for high income

household, the convenience, comfort and benefits on environmental quality and human health are considered in the fuel choice. For biogas, the supply of raw material, the quality of biogas generating pool and the quality of biogas affect its use significantly.

2) Household and setting characteristics, including factors like family size, age, gender, household income, location and structure. Without doubt, the house income affects the adoption behavior significantly. With the increase of house income, it is possible for most residents to adopt cleaner commercial fuels so as to improve the living conditions. The consumption of biogas increases with the income increase at the very beginning, and after a critical value of house income, the biogas consumption decreased with the income increase. Most residents would change to other cleaner and renewable fuels like LPG.

The location and structure of household are also found to correlate with the fuel choice in some area. In families with concrete structure, people prefer to use cleaner commercial fuel, which is related to the relatively high income of the household. The influence of location is related to the abundance, accessibility and cost of different fuels. In most remote area, the commercial fuels like natural gas and LPG are expensive in comparison with nearly free biomass fuels and cheap coals. The development of biogas is also determined by the local conditions like ground temperature and solar energy resources.

In terms of the size, age and gender of family members, the young prefer to use cleaner high-quality fuels while the old are used to traditional solid fuels in daily cooking and heating. Because of the scale effect, the fuel utilization efficiency is generally higher in large size family (4-5 members) compared to the family with less than 3 persons. In addition, with more people in home, there would be enough labors to use and maintenance the biogas pool so as to continuously support the biogas fuel. Compared to the male in family, the female are preferably to adopt cleaner new fuels since they, in most cases, conducted the cooking and heating activities in home, and thus expose directly to incomplete pollutants emitted from the domestic burning.

Besides, changing to cleaner fuels with relatively high burning efficiency would reduce the total time spent, decrease fuel consumption amount and free the labor to do other works which additionally increased the house income.

3) Knowledge and perception. The knowledge and awareness about fuel characterization and potential benefits after adoption of residents are positively correlated with their adoption willing and enthusiasm. Through the publicity of new fuels and cookstoves, and through the demonstration from the around, there would be more and more residents know about these new fuels and cookstoves, and would participate into the adoption group.

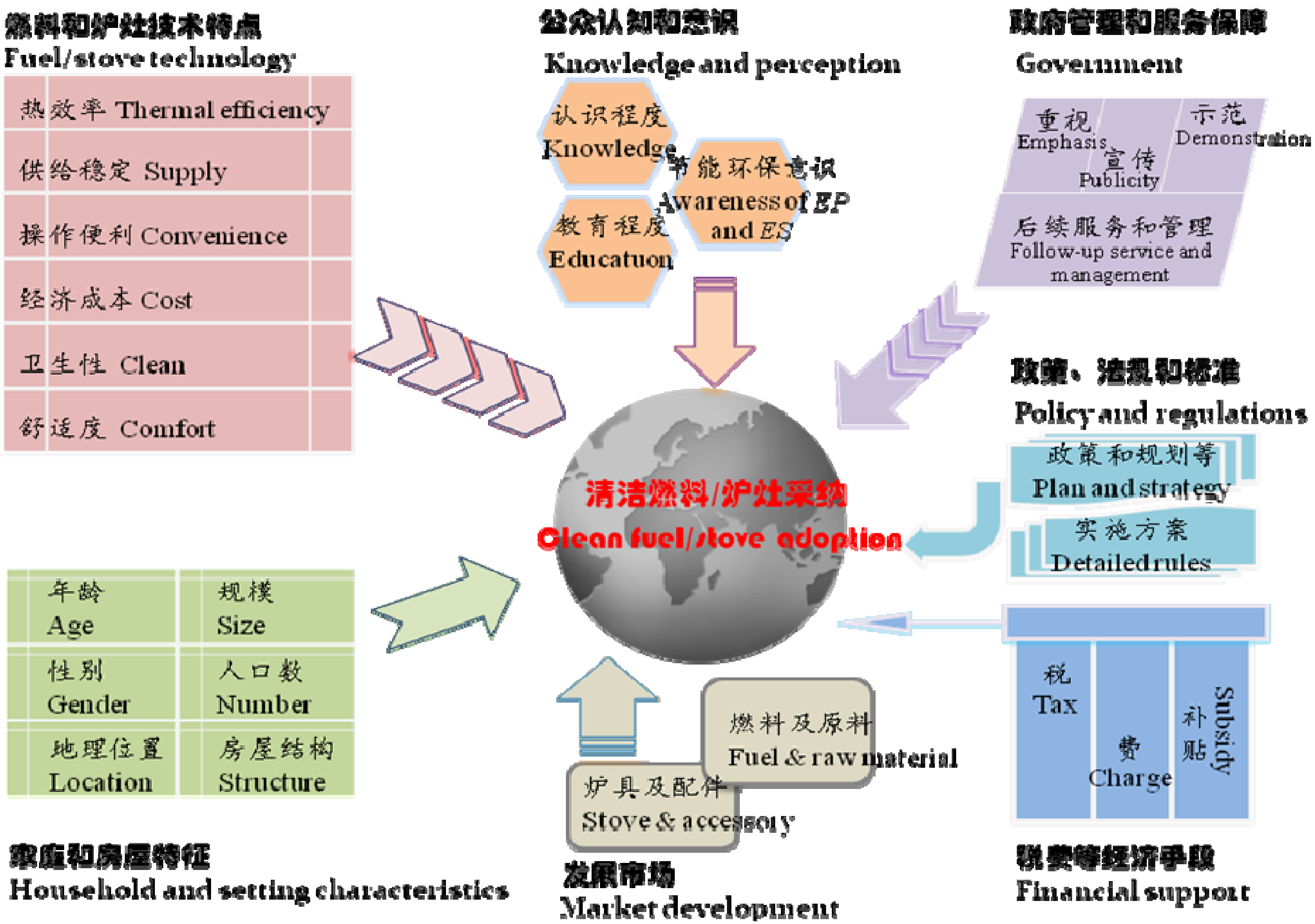
Generally, with a higher education level, it is easier to adopt new things, which means to use cleaner fuels and cookstoves in the present study. The education is spreading in China, which is good for the deployment. But it is also realized that more rural residents go to look for work elsewhere and migrate into the urban and big cities after graduation which to some extent is a limiting factor for the development of biogas in rural area since it requires relatively large labor to maintenance the gas production.

4) Policy and regulations. The adoption would be promoted under the support of beneficiary macro-policy, detailed regulations and rules, It is important to decide distinct rules and regulations to different areas.

5) Financial support. Through the ways of low tax and subsidy, financial support from the government would increase the adoption willing and more important the adoption behavior at the very beginning facilitate without an increase of residents' financial cost.

6) Market development. It is important to guaranteeing the sustainable use of cleaner fuels and stoves after the adoption with a good development of fuel, stove as well as stove accessory market. The beneficiary policy will also facilitate the market development.

7) Governmental role. The role of government is in particular important in a deployment program in China. The publicity, demonstration and after-sale services of new fuels and stoves would increase the enthusiasm and willing in adoption. With the emphasis of government officers, a professional team would guarantee the service and technical support during the initial adoption and sustainable use.



燃料和炉灶技术特点
Fuel/stove technology
热效率 Thermal efficiency
供给稳定 Supply
操作便利 Convenience
经济成本 Cost
卫生性 Clean
舒适度 Comfort
公众认知和意识
Knowledge and perception
认识程度
Knowledge
节能环保意识
Awareness of EP and ES
教育程度
Education
政府管理和服务保障
Government
重视
Emphasis
宣传
Publicity
示范
Demonstration
后续服务和管理
Follow-up service and management
政策、法规和标准
Policy and regulations
政策和规划等
Plan and strategy
实施方案
Detailed rules
清洁燃料/炉灶采纳
Clean fuel/stove adoption
年龄
Age
规模
Size
性别
Gender
人口数
Number
地理位置
Location
房屋结构
Structure
家庭和房屋特征
Household and setting characteristics
燃料及原料
Fuel & raw material
炉具及配件
Stove & accessory
发展市场
Market development
税
Tax
费
Charge
补贴
Subsidy
税费等经济手段
Financial support

Acknowledgement

We appreciate the opportunity to conduct a literature review on the factors affecting the adoption and sustainable use of cleaner fuels and cookstoves in China. Although based on more than fifty thousand papers, fuel read of 351 papers and extracted data from final 87 papers selected for in-depth review, some critical factors were identified, we realized that there are many questions and thoughts that can hardly be answered at this stage. For instance, the qualitative impacts of some factors were mentioned without a sound and quantitative result. And, the stove type and fuel technologies vary significantly in China. The spatial, as well as temporal variations should be taken into the consideration. We hope the results from the present study can help the researchers and those who aim to deploy the fuel and stove adoption program to better design and promote the cleaner fuels and cookstoves in future. But, because of limited abilities of the authors, we truly believe that there might be something important was ignored, and part of the conclusions can not be generalized too much because of scarce support from the literature. It is expected that with the efforts from both government, research institute and organization who are interested in the development and deployment of cleaner fuels and stoves, the inadequacy and deficiencies of the present study can be solved.

The study was financially supported by the Global Alliance of Clean Cookstoves (GACC, RFP-31). We thank the help of Miss Sumi and Mr. Wu from GACC in the design and implement of the program. We kindly appreciate the comments and valuable suggestions by Prof. Shu Tao (Peking University), Prof. Guangqing Liu from Beijing University of Chemical Technology and Prof. Xiaoli Duan from Chinese Research Academy of Environmental Sciences.

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April 2014, Nanjing

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1. Introduction

1.1 Background

Globally, over three billion people use solid fuels mainly including coal, crop residues and woody materials as the main household energy source, and more than 90% of the consumption occurred in developing countries. During the last three decades, although the percentage of people using solid fuels has decreased due to the improvement of living standard, the total number of people exposed to severe air pollution from residential solid fuel combustion remains very large because of a rapid increase in the population (Bonjour *et al*., 2013). Due to lower combustion efficiency leading to relatively high emissions of incomplete pollutants per mass fuel or per task) and a large consumption amount, residential solid fuel combustion usually emits a large number of various compounds, like gaseous CO, NO_X, SO_2, particulate matter with complex chemical compositions, as well as CO_2. As a consequence, residential solid fuel combustion affects local/regional air quality to a large extent, and also influences human health and climate change (Anenberg *et al.,* 2013). Globally, exposure to smoke from residential solid fuel combustion is the 2nd (female) or 5th (male) largest risk factors among the 67 investigated risk factors, resulting in approximate 3.55 million premature death and 4.5% global DALYs (disability-adjusted life years) in 2010 (Lim *et al.,* 2012). The risk is even higher than that exposure to outdoor ambient particulate matter and ozone, and making it the largest single environmental risk factor in many developing countries.

Pollutant emissions from the combustion process are influenced by a variety of factors including fuel property, stove design and fire management. Generally, it is believed that improved stoves with relatively high burning efficiency could result in the alleviated air pollution, lower fuel and energy consumption, free women time and benefits for human health *etc.* In the last several decades, several regional or national programs have been deployed by the local government, regional community or non-governmental organization to improve combustion efficiency, reduce indoor air pollution and protect human health through the adoption of cleaner fuels and high efficient (improved) stoves (Puzzolo *et al.,* 2011). In addition to achieve successful improvement in fuel saving, air quality, human health and social welfare, these initiatives also demonstrated that there was great potential for easing the burden of cooking over rudimentary or traditional low efficient stoves, and more important, it is possible to get support, not only financial support but also technical supply, from influential leaders and local or international organizations all over the world (Anenberg *et al.,* 2013).

To achieve real desired benefits, it is essential and also important to take the effectiveness and sustainable use of the new fuels and/or stoves through the programs or interventions. At the very beginning, it is generally very difficult to deploy new designed stoves or alternative fuels in most households since it may change the cooking habits and also increase economic burden of the residents. Usually, under the support of local or national government and financial welfare, "new" stoves and fuels could be deployed widely. However, another thing of concern is whether it can last for a long time. Experiences from Chinese National Improved Stoves Program and India's National Improved Stove Program gave contrary answers. It is critical to study on the key factors influencing the adoption of cleaner fuels and improved high efficient low emission stoves.

Recently, Puzzolo and co-workers (2011) from the UK department for International Development, University of London, reviewed over one hundred studies from Asia, Africa and Latin America to identify the key factors affecting the deployment of improved stoves and clean fuels. It is satisfied to see the study based on a comprehensive and systematic search strategy is able to assess several key enablers and barriers in the improved stove and clean fuel deployment. However, in their study, Chinese peer-reviewed literatures were not included, although the experience from Chinese National Improved Stove Program resulted in positive benefits in both air quality and human health.

1.2 Significance of Chinese studies

Severe air pollution in China has attracted high worldwide attention (Anenberg *et al.,* 2010; Brauer *et al.,* 2012; van Donkelaar *et al.,* 2010). It had estimated that the premature deaths attributed to the ambient air pollution in China were about 350-400 thousands, and the economic burden of premature mortality and morbidity was conservatively estimated at about 157 billion RMB (1.16% of the GDP) in 2003, and may as high as 520 million according to the willing-to-pay estimation (World Blank, 2007; Zhang *et al.,* 2007). Due to large consumptions under relative efficiencies in residential stoves, residential solid fuel (coal and biomass) combustion emitted large numbers of incomplete pollutants in China. It is estimated that residential solid fuel combustion produce about 14-20, 23-35, 33-47, 82-91, 46-67, 9.2-10, 9.0-11, and 62% of primary TSP, PM_{10}, $PM_{2.5}$, OC, BC, SO_2, NOx, and PAHs in China (Lei *et al.,* 2011; Shen *et al.,* 2013; Wang *et al.,* 2012; Zhao *et al.,* 2013; Zhang *et al.,* 2008). During 1982-1992, a national improved stove program was conducted in China which introduced about 129 million improved stoves into rural areas. It is estimated that more than two-thirds of the stoves were still in use, making the program well known in the world (Smith *et al.,* 1993).

In view of the potentially large benefits associated with abatement of indoor burning of solid fuels, knowledge of which factors are responsible for successful adoption of clean cookstoves and new fuel-devices is of obvious importance. And since interventions have globally given varying results and haves often been unsuccessful, the cumulative experience of China in conducting improved cookstove programs will provide valuable information for future work. As such, it is no doubt that China has successful experiences of others to go by.

1.3 Objective

Since the study by Puzzolo and co-authors did not include peer-reviewed Chinese publication, Global Alliance of Clean Cookstove (GACC) decided to support a literature survey and review study on the identification of key factors affecting the deployment and sustainable use of clean fuels and cookstoves in China. This is the main objective of present study.

The present study adopted the search and analytic approach (using similar investigation tabulations) in Puzzolo *et al.,* (2011)'s review, so as to keep consistent with the protocol used in the larger systematic review. Translation in Chinese for these terms is not simply a matter of seeking words with similar meaning, but of finding appropriate terminology that is commonly and frequently used in Chinese language literature.

2. Method

2.1 literature search and keywords

Table 2.1 Search terms

Intervention/fuel	AND	Uptake	OR	Programme*
stove/ cookstove cooking stove		adoption		National Improved Stove Program/ NISP
cook AND technology		accept/uptake		Ministry of Health AND improved kitchens
High efficient low emission stove		deliver		
Fuel-saving stove		choice/ switch		Yangtze River Valley Environmental Protection Project AND stoves
cook AND fuel		dissemination		
liquid petroleum gas		scale		Other medium or small scale programme
pipelined gas		Household/ domestic		
natural gas		residential		
electricity		Rural/country		
biomass/ biogas				
fuelwood/ firewood				
coal				
honeycomb briquettes				
Charcoal				
energy				
Biomass pellet				

* The programmer listed in the table will be independently searched in the electronic databases

Eligible studies were identified from the database according to the designed search terms and keywords. The papers were classified, screened, and in-depth reviewed. Standard operation procedure (SOP) for literature screening was established. Peer-reviewed publications were identified from the database of China National Knowledge Infrastructure, Wanfang Data and VIP Journal integration platform, Chinese Science Citation Database and Chinese Social Sciences Citation Index up to October, 2013.

The search terms used in the UKID protocol were adopted in the present study, but with a minor adjustment according to local names for stoves or fuels in China. The search terms are listed in Table 2.1 in both English and Chinese. Translation in

Chinese for these terms is not simply a matter of seeking words with similar meaning, but of finding appropriate terminology that is commonly and frequently used in Chinese language literature. The terms in the first two columns in Table 2.1 were combined with Boolean search function 'and'. Extend search for literature within some famous improved household stoves programs was also conducted, using the program name or agencies as search terms.

2.2 literature screening and classification

The study team was separated into two groups with three persons in one group. The two groups conducted the literature search respectively and the results were compared and combined. Duplications were removed from the total number of studies found from multiple database searches. Remaining articles were reviewed independently by two authors according to inclusion/exclusion criteria based on title and abstract. Any discrepancies were adjudicated by the third author. The criteria are based on the following components: (1) clear aim and objective; (2) adequate description of context; (3) appropriate study methodology (i.e. sampling, data collection and analysis). The individual studies were assessed according to 6 criteria and graded into 'high', 'moderate' and 'low'. A study with a final grade of very low was excluded based on inadequate quality.

These publications were classified into qualitative study, quantitative study and case/policy study.

- **Qualitative studies** followed qualitative methods such as semi-structured/structured interviews, focus group discussions (FGD), observation techniques, recalls, etc.
- **Quantitative studies** different from the qualitative methods usually follow quantitative methods such as empirical measurements, regression analysis and statistical models based on collected data and information in real practice.
- **Case/policy study** provides insights on problems and countermeasures

on the fuel consumption structure, cleaner fuels and improved stoves during the adoption based on a project/programme. The study followed the roadmap showing in **Figure 2.1.**

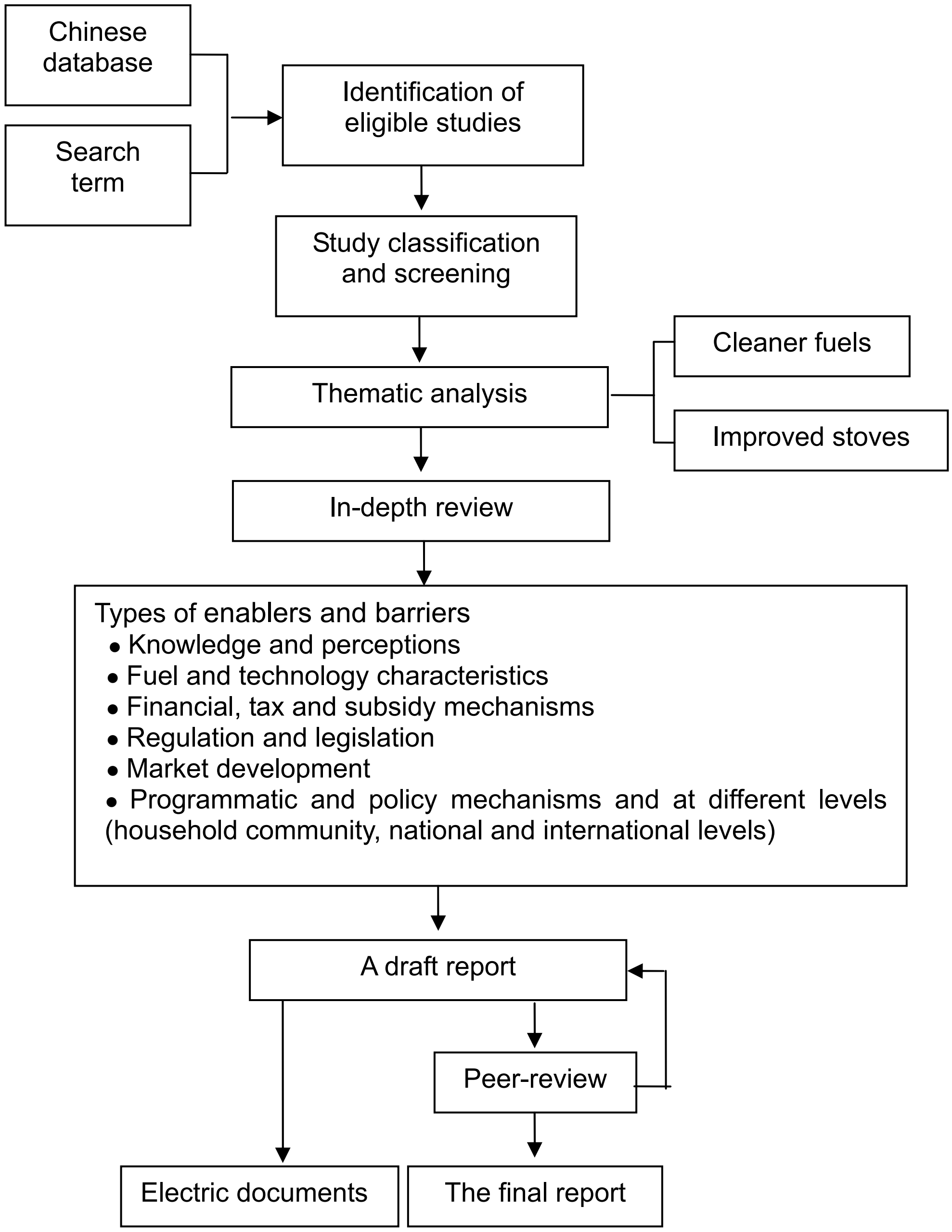

Figure 2.1 Study roadmap

3. Results

3.1 literature search results

3.1.1 Studies identified

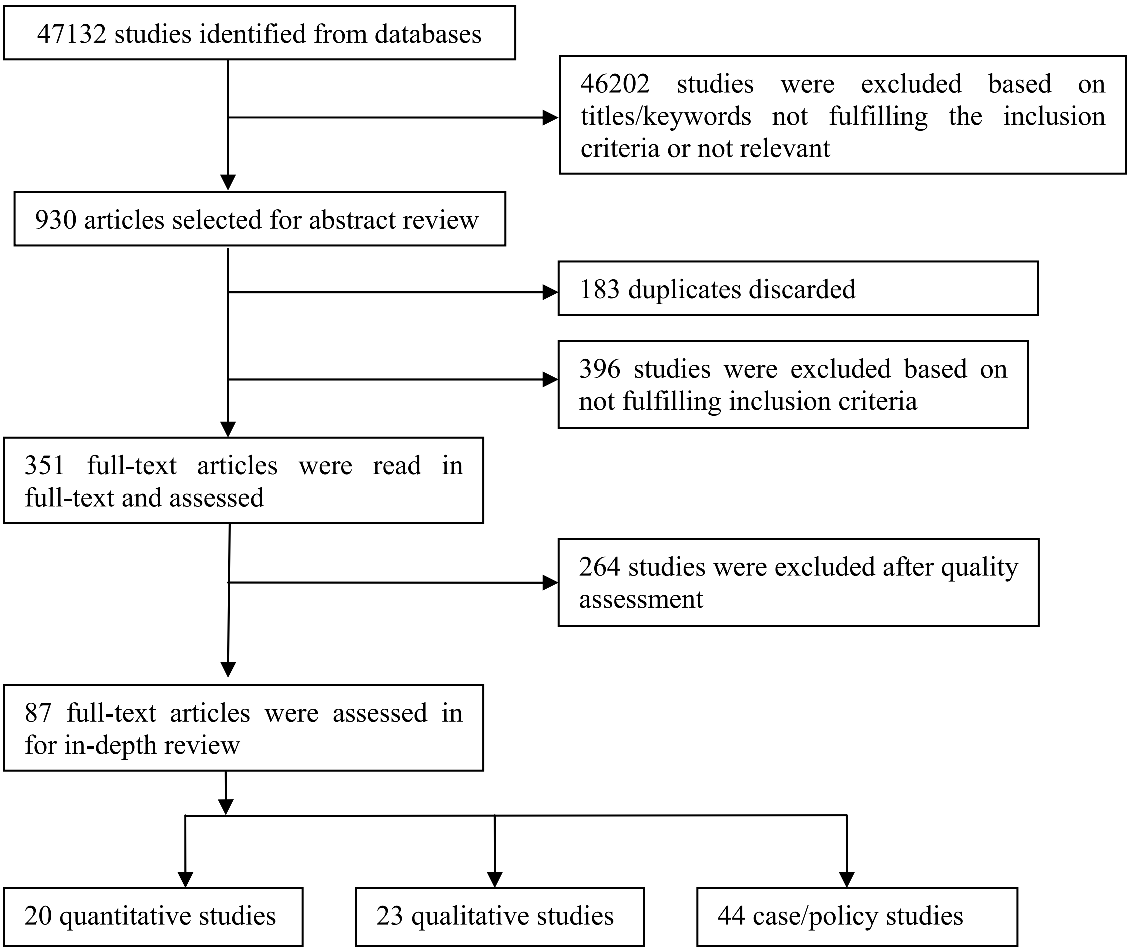

Figure 3.1 Literature search trial flow

47132 records were found from the databases. After initial screening of the titles, we selected 930 articles for abstract review, and 351 articles were selected for outcomes of interest, and of that 87 ones were read in full-text. Among the 87 finally deep analyzed papers, there are 20 quantitative studies, 23 qualitative studies and 44 case/policy studies. Data and main results were extracted from these 87 papers and key enablers and barriers affecting the adoption and sustainable of clean fuels and cookstoves were identified.

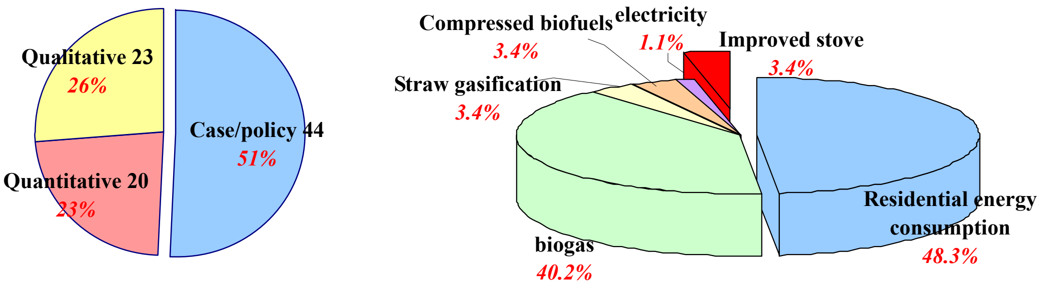

Figure 3.2 the proportion of identified studies reporting factors affecting the adoption and sustainable use of different fuels and cookstoves

3.1.2 Study spatial distribution

Studies covered most areas of mainland China. Among 87 studies, 20 were based on the national statistical data or general situation in China so that the analysis of influencing factors was in the view of a general situation in whole China.

Among the other 67 studies, most of them were conducted on a specific situation in the local area. There were 13 studies in Jiangsu provinces and 9 studies reporting the situation and influencing factors of cleaner fuels and stoves in Shanxi (Figure 3.3). Figure 3.4 also shows the spatial distribution of quantitative studies identified. It can be revealed clearly from these two figures that there were very limited studies, particularly quantitative studies nowadays on the influencing factors of cleaner fuels and cookstove adoption. Because of distinct differences in population and pollutant emission densities in different provinces in China, and large spatial variations in social-economic development conditions and personal habits, although some study in the view of whole china can identify several key factors in fuel and stove adoption, local studies focusing on the specific situation in targeted provinces, or even county level if possible would be preferable.

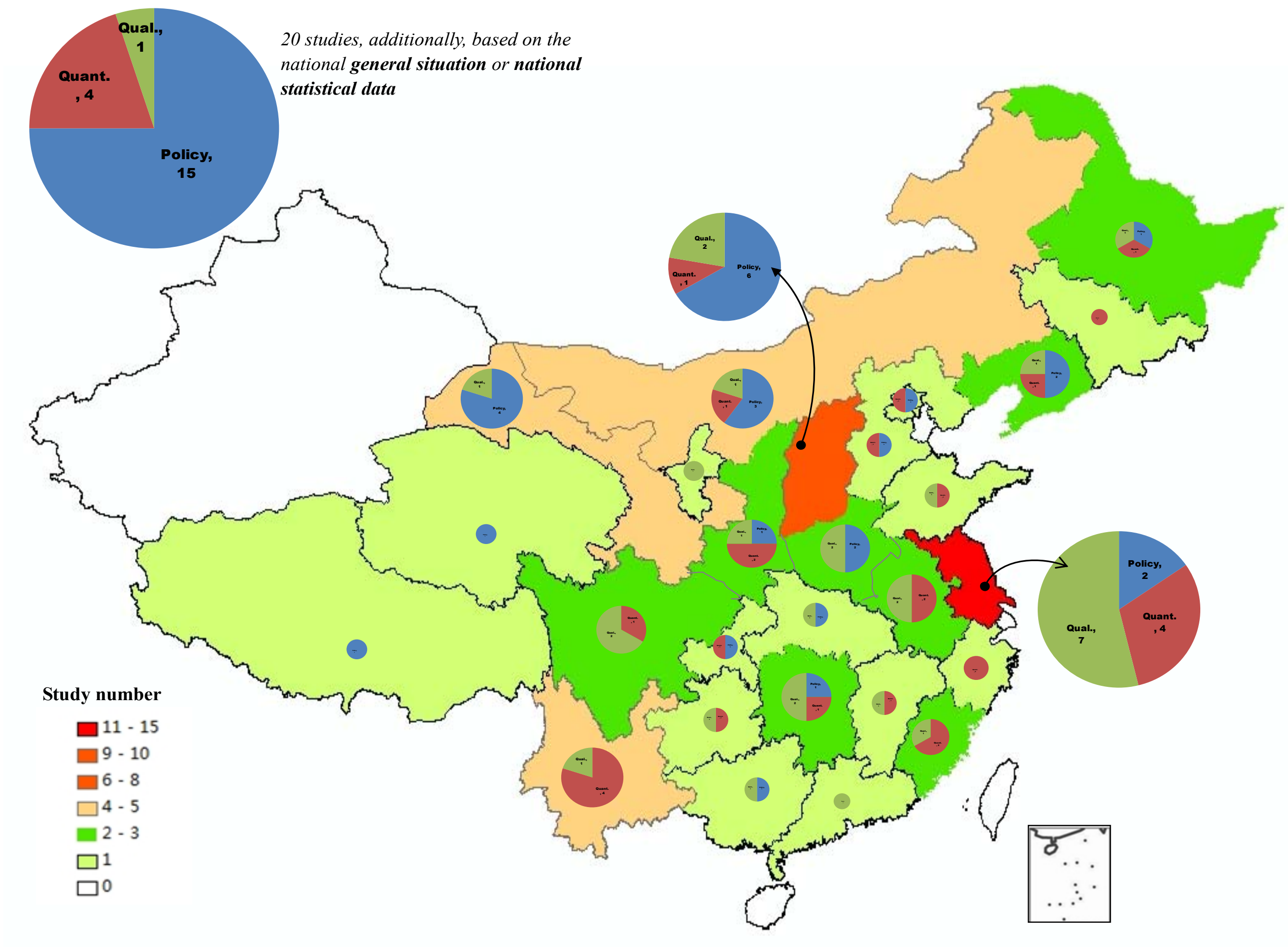

Figure 3.3 the number of studies in different provinces in mainland China

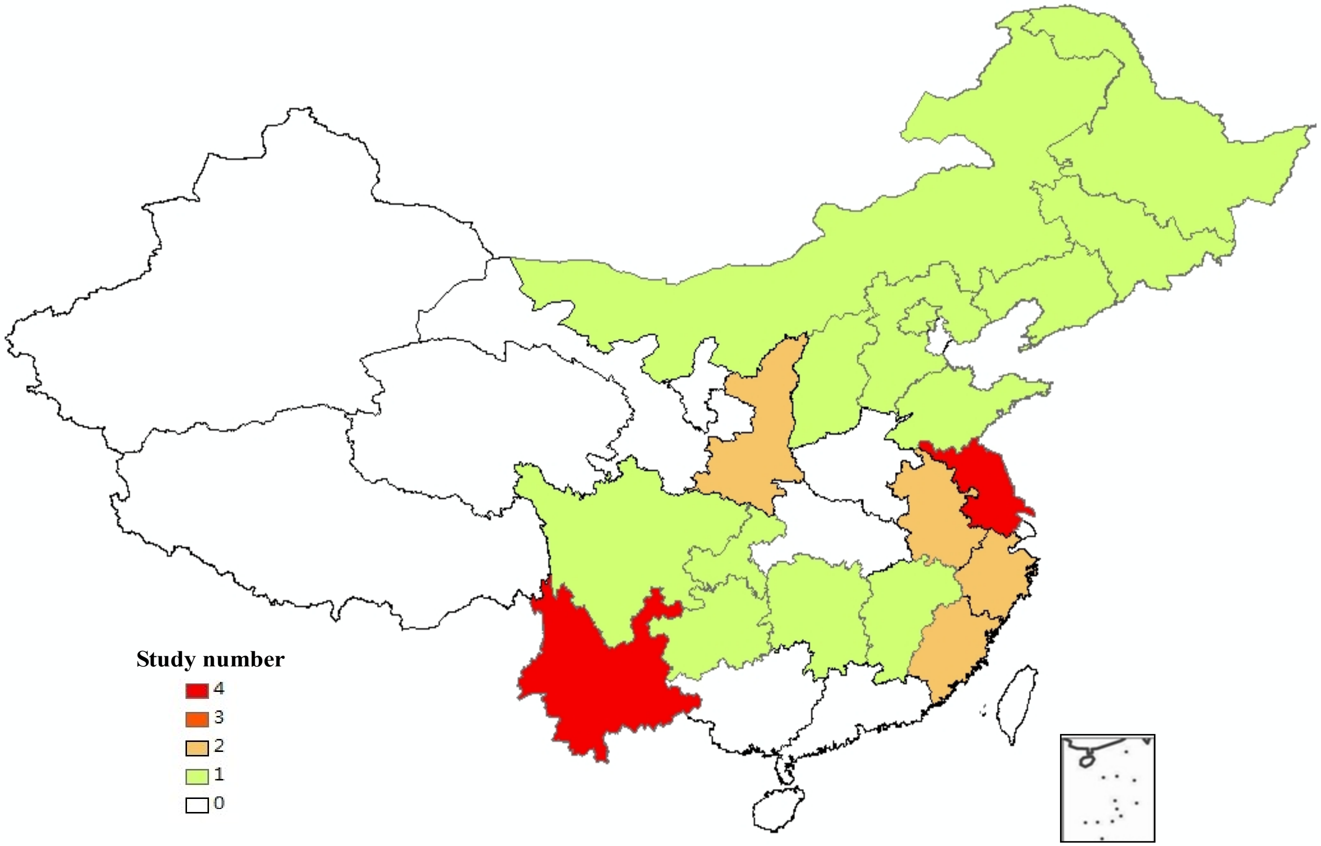

Figure 3.4 the number of quantitative studies in different provinces in mainland China

3.2 Results

3.2.1 development of cookstove

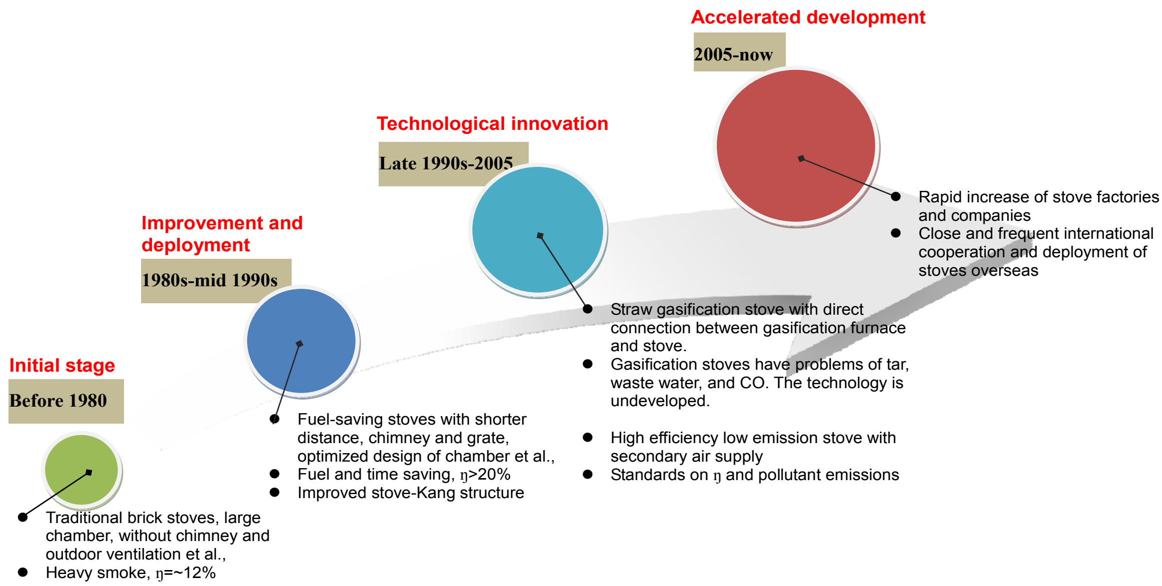

Figure 3.5 the development of household stove in China (Zhang *et al.*, 2008)

The development of household stove in China can be classified into four stages:

1) Initial stage, before 1980. In the period most of the stoves used were traditional hand made ones, and are brick structure. Stoves used in this stage are associated with problems like large distance between wok and ground, large stove door and chamber, no grate and chimney, which usually resulted in large energy lost, and subsequently leaded to low efficient combustion and pollutant emissions. The thermal efficiencies of these traditional stoves were usually around 12%.

2) Improve and deployment stage (1980s-mid 1990s). During the 1980s, the deployment of cookstove was included in the sixth “Five-year” plan in China, and by 1990s, more than 0.2 billion stoves were deployed in rural area. In comparison with traditional stoves, the improved stoves had the optimization of stove chamber, the distance between wok and ground, installation of chimney and grate, optimized ventilation conditions *et al.,* The installation of chimney would form a negative pressure in the chimney, which is favorable for the exhaust of smoke and improve indoor air quality (Hu et al., 2008). With higher chimney, higher negative pressure would increase the smoke rate and facilitate the burning. However, higher chimney would also result in larger heat lose, which should be noted in the installation of chimney. The thermal efficiencies of improved stoves are higher than 20% in general. The fuel-saving stoves could save fuel and time, are easier in use and clean. Meanwhile, in many areas in north China, improved stoves are connected to optimized *kang* structure.

3) Technical innovation (late 1990s-2005). In this period, some straw gasification stoves came into use. These stoves connected the gasification furnace and stove directly, but because the gasification conditions can not be controlled and the supply and quality of gas vary dramatically which results in problems in stove adoption and safe use. It needs to treat tar, waste water and CO pollution in the use of this type of stove. Therefore, the stove should not be under large scale deployment before the development of technology. Another type of typical innovated stove is high efficiency low emission stoves, which have the secondary air supply from the top beside the primary air supply from the bottom. It is generally accepted that stoves with the following characteristics can be classified as "high efficient low emission stove"-***thermal efficiency***: > 35% for a cooking stove, > 60% for a cooking and heating stove and > 65% for a heating stove; ***smoke emission:*** < 50 mg/m^3, ***SO_2, NOx and CO emissions***: <30 mg/m^3, <150 mg/m^3, and < 0.2%, respectively. Some widely used stoves include (Hao, 2009):

✓ Cooking stove. Recently more than 500 thousand cooking stoves have been deployed in rural area. Two stove companies from China was rewarded "Ashden renewable energy price" in 2007 and 2009, respectively. The cooking stove can be typically classified into two types of natural ventilation and forced draught. It was reported that with a 3 w blower, the use of 1.2 kg fuels can evaporate 4.3 kg water. The burning efficiency can be high as 92% and thermal efficiency was 51.8%. With natural draught, the use of 2 kg fuels can evaporate 4.65 kg water and the thermal efficiency can reach 44%.

✓ Improved commercially fuel-saving stove. In the standard issued by MOE in 1987, it is required that the thermal efficiency of a certified stove should be higher than 25%. In practice, some commercial fuel-saving stoves with secondary air supply and iron structure have thermal efficiency higher than 35%. More than 100 thousands stoves of this type have been deployed in provinces like Yunnan, Guizhou and Sichuan. The stove can use a variety of fuels, which means the residents are not necessary to purchase fuels to suit the stove, and after the change, fuel consumption reduced.

✓ Heating stove. About 40 thousands were deployed in the last several years. The heating stoves in north China can be heating only stoves, cooking-water heating stove, and cooking-water heating-smoke *kang* structure.

✓ Boiler using compressed fuels. In the urban area, some enterprises with heat supply area between 400 and 20000 m^2 can use the compressed fuels to replace coal in heating. The benefits are obvious, and there is a tendency in large scale uptake in cities like Beijing, Tianjin and Changchun.

4) Accelerated development (2005-now). After 2005, there is a rapid increase in stove factories and companies. The production of some companies can be high as 30 thousands per year. The R&D on stove technology has been fast promoted. Meanwhile, there are more and more international cooperation in forms of publicity, meeting and experience exchange activity.

In the last several years, some institute in China designed and tested a variety of cookstove that can be used for the burning of compressed fuels or wood logs. Liu et al., (2009) designed a stove with one single wok and using pellets as fuel (Figure 4.2-A), the test showed that the burning of fuel in this type stove is steady, and thermal efficiency was 41.3%, the CO and NOx concentrations in smoke were 0.11% and 0.03%, respectively. The Ringelman black is less than 1.0. All tested parameters reach national standards. Wang et al., (2008) investigated the influencing factors on pelletized fuel burning in a specific burner (Figure 4.2-B). The results showed that the slagging rate was only 3.5% under the optimized excess air ratio of 1.5. The slagging rate increased with the raise of combustion temperature, the increase of excess air and increased fuel layer thickness. Some companies and university designed different types of cooking stoves that is aimed to be deployed in rural China. Fan et al., (2010) tested 3 different fuel stoves (Figure 4.2-C), and optimized the structure of stove after the test experiment. The results showed the thermal efficiency and pollutant emissions for these stove can achieve to the national standards, for example, the thermal efficiency of one stove was 35.6%, smoke and NOx concentrations were 16 and 65 mg/m^3, respectively, CO was 0.03% and excess air ratio was 1.78.

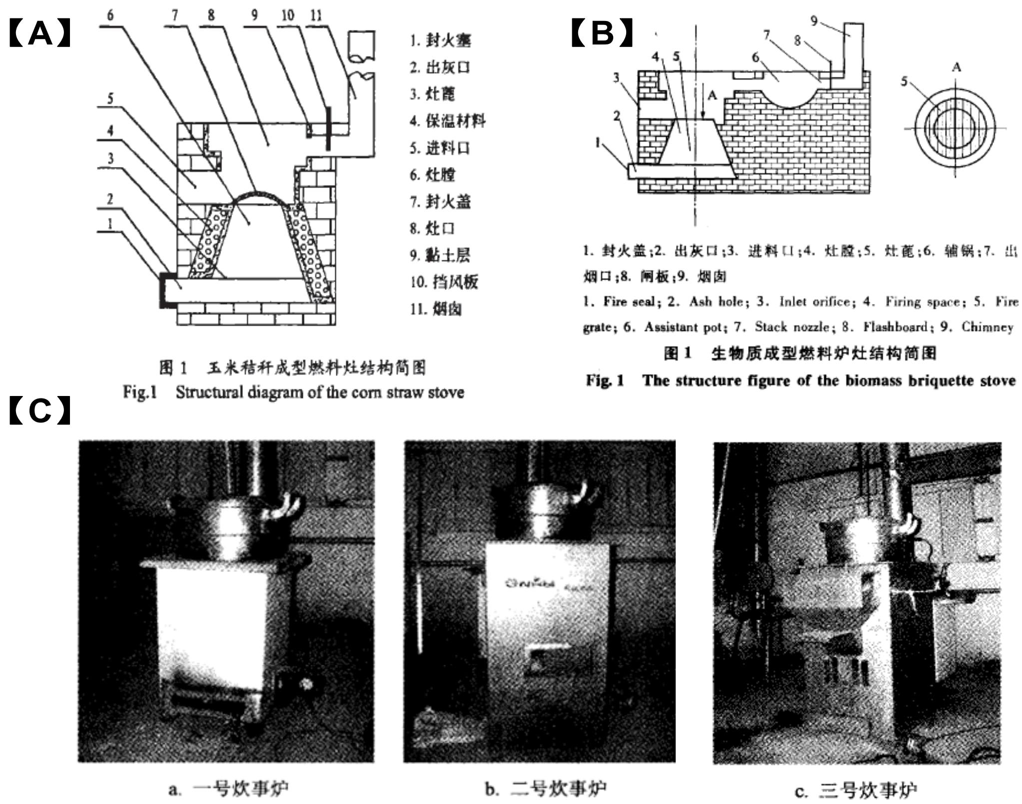

Figure 3.6 several examples of household stoves in test and under deployment in China

3.2.2 Influencing factors of cleaner fuel adoption

There are a variety of subjective and objective factors affecting the uptake and sustainable use of cleaner fuels in rural household, including fuel and stove technology characteristics, policy and standards, market development, financial and subsidy, awareness and perception, and the support and emphasis from the local government, the publicity, after-sale service and so on.

In most Chinese peer-reviewed literatures, they focused on the change of household energy consumption structure which showing the proportion of traditional solid fuels including wood, crop straw and coal, and relatively cleaner fuels like biogas, electricity, liquid petroleum gas (LPG) and solar energy. Among these studies, there were 15 policy analysis, 14 studies are qualitative analysis based on questionnaires and interview, and 13 studies are quantitative studies (**Figure 3.3**).

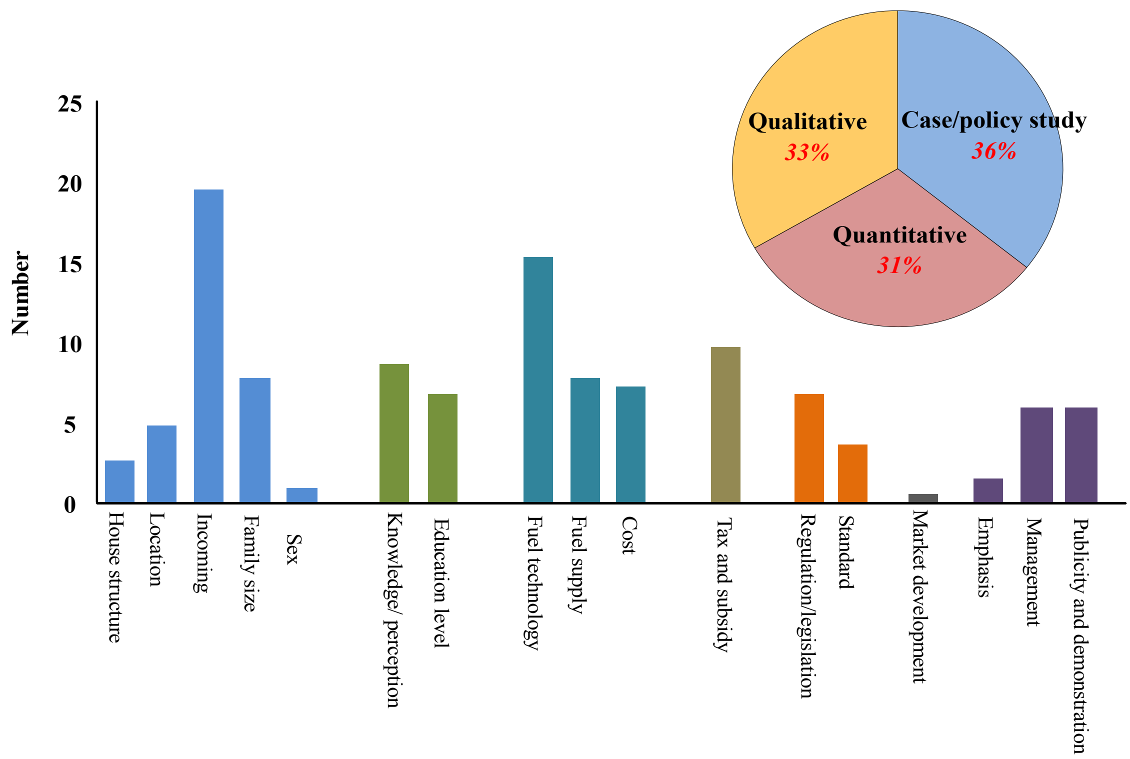

Figure 3.7 number of studies of different influencing factors affecting the energy choice in household consumption

4. Factors influencing cookstove uptake

In the late 1990s, the deployment of improved fuel-saving stoves achieved very slow progress, and the main reason was that the adoption of these stoves put particular emphasis on thermal efficiency instead of the practicably (Peng, 1998). The problems included that 1) stove door was so small that which only small branches or straw can be inserted, 2) stove chamber was so small that fuels had to be inserted into the chamber in many times and the operator can not leave during the combustion processes, 3) complex flue pine that can easily stick down smoke and require a clean maintenance, 4) not convenient in use especially when it is necessary to boil water and cook food. It is suggested that by adding a grate, the stove may be suitable for the use of a variety of fuels, by adding a pot on the top, the residual heat may be used to heat water, by optimized design of height and position of wok, the stove may be more practicable.

Although the deployment of fuel-saving cookstoves during the 1980-1990s achieved great success, most of the stoves currently used in rural area are built by the residents themselves, which heavily depends on the experience of the residents. The lacking of the technical specs and incomplete development of domestic cookstove market result in a variety of low quality stove in use (Guo, 2011). It is thought that the market development and stove technology characteristic were important factors affecting the large scale deployment of these new fuel-saving fuels in China. Liu *et al*., (2011) analyzed the status, problems and countermeasures for the deployment of high efficient low emission stoves in Shanxi province. In the study, no clear definition of “high efficient low emission stove” was provided. They indicated the key enablers included the fuel briquetting technology, the optimization and sustainable supply of stove and stove accessories, and also financial support from the local government. The results from 180 questionnaires in Henan province showed that the deployment and use of the improved fuel-saving stove was rough and out-of-order (Tang *et al*., 2011). The local government did not effectively guide the residents to adopt and use the improved stoves. Also, the lack of technical specs and standardized management, no awareness and perception of energy saving and environmental protection, and indifference to the development of new technologies are reasons causing the unsatisfactory deployment status.

Thus, factors affecting the deployment and sustainable use of new stoves identified in Chinese literature include:

1) ***Stove technology.*** The design of commercial stoves should be good for the efficient burning and convenient use. For the self built brick stoves, the stove quality affects the adoption and sustainable use obviously.

2) ***Policy and standards.*** The development of regulation, legislation and standard is essential for the effective deployment, particularly the later. To ensure the quality of stoves, exacting standards are necessary.

3) ***Market development.*** As identified in one study, the development of market supplies the stove and accessories continuously.

4) ***Tax and financial support.*** Either the purchase of commercial stoves from the local market or self-built brick stoves in home requires additional expenditure. If the adoption can be support financially, the residents would be more willing to use the deployed stoves.

5) ***Knowledge and perception***. When it is realized the adoption can save fuels and benefit the environmental quality, the awareness of energy-saving and environment protection would promote the residents' adoption behaviors.

6) ***Demonstration and management.*** This means the emphasis and encourage from the local government, especially the local leaders, advertisements on new stoves and advantage of adoption and demonstration of other users are important enablers of the stove deployment.

5. Factors affecting cleaner fuel adoption

5.1 Household characteristics

1) House structure and area. Liu *et al*., (2013), Zhang *et al*., (2011) and Wang *et al*., (2012) analyzed the influence of house structure and area on energy consumption. The study by Zhang *et al*., (2011) was conducted based on the investigated data from 9 provinces including Jiangsu, Guangdong and Liaoning in East China, Heilongjiang, Jiangxi and Shanxi in Middle China, and Guangxi, Shaanxi and Guizhou in West China. They found that in comparison with the family living in houses of brick-wood structure, those who live in concrete structures prefer to use cleaner high-quality energies like electricity and solar energy, and the chance of using cleaner high-quality energies increased by about 5.67%. The chance would also increase by about 0.01% with per 1 m^2 increase of house area. Liu *et al*., (2013) found that in the western Hunan province, firewood was the main household energy in adobe structure, contributing 72% of household energy consumption, coal briquette and LPG were main energies in brick-wood structure comprising up to 57 and 21% of total household energy consumption, and in concrete structure the consumption of LPG and coal briquette contributed over 48 and 32%, respectively. To a great extent, the difference in household structure is the difference in family income. With the increase of house income, it is believed that more and more residents would be overhauled, and in new house some modern living appliances like modern stoves and electrical equipments would be equipped, and thus the consumption of cleaner high-quality energies such as electricity and LPG would increase.

2) Location. The influence of house location is the main reason for the availability and accessibility of various fuels (Gao, 2009, Chen and Zheng, 2009; Wu *et al*., 2012; Qiao, 2010, Wang *et al*., 2007). In most inconvenient remote area, the consumption of traditional fuels like firewood are very large while a high price and the difficult in the transport of cleaner fuels like coal briquette and LPG prevent the use of these fuels in daily lives. In these areas, the development of biogas might be an alternative if the location was good for the biogas development (more detailed discussion on factors affecting biogas uptake is in the next section).

3) House income. The influence of house income is significant (Cai and Zhang, 2006; Chen and Zheng, 2009; Wu *et al*., 2012; Zhou *et al*., 2009; Fei and Yu, 2011). It was found that among various influencing factors, the marginal utility of house income is the most significant (Zhang *et al*., 2011). Generally, the adoption of cleaner high-quality fuels increases with the increase of house income. In practice, it was found that that consumption of electricity increased significantly with the increase of house income (Wang and Hu, 2010; Feng and Wang, 1996.The relationship between biogas consumption and house income is non-linear, usually in the form of quadratic curve that is the adoption willing increased with the increase of house income in the beginning, but after a critical value, the consumption decreases with the income increase as the residents may be preferable to use other cleaner commercial fuels like LPG (Wu *et al*., 2012).

In the Expanded Linear Expenditure System (ELES) model, the marginal propensity to consume (MPC, β) can be used to suggest how the residents would arrange the income on different fuels after the basic consumption need was met. A lower β value may indicate a higher tendency to adopt the fuel. Zhang and Niu reported that, with per 1 RMB increase of income per capita, there would be 0.044 and 0.065 RMB used for household energy for urban and rural residents, respectively (**Figure 5.1**). For urban residents, the MPC of coal is negative suggesting the reduction in coal use after income increase. Both results from urban and rural areas showed that with income increase, there would be clear tendencies in the use of clean commercial fuels in household energy consumption. The study by Zhang et al., (2010) based on the survey in Fujiain, Jiangxi, Zhejiang, Anhui, Hunan, Shandong, Liaoning and Yunnan showed that most households use 2 or 3 different fuels simultaneously. With per 1 RMB increase in house income per capita, there would be 0.0710-0.1557 used for household energy consumption. The MPC of household energy decreased among groups with increased house income (**Figure 5.2**). It again clearly showed that with the increase of house income, the use of cleaner fuels like biogas and electricity is preferable.

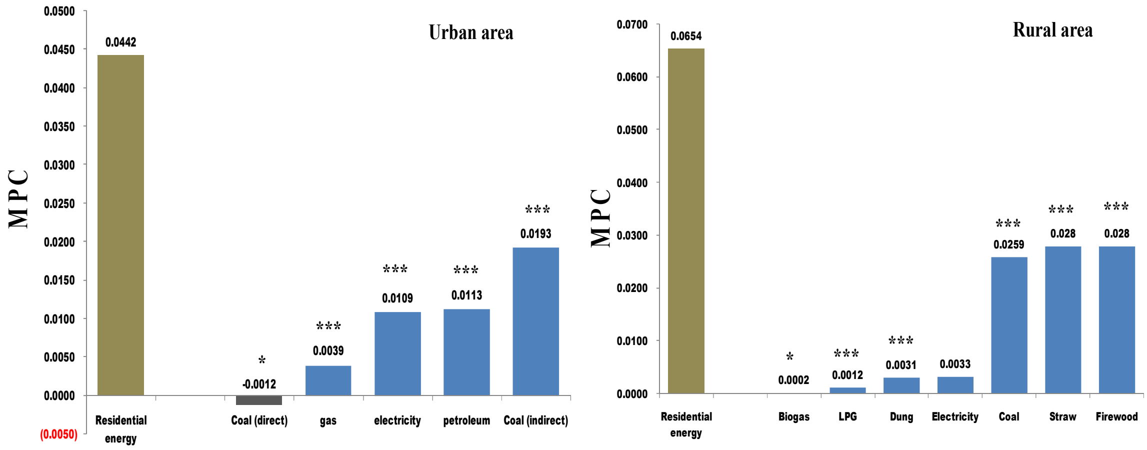

Figure 5.1 the marginal propensity to consume (MPC) of different fuels in urban and rural residents with one income increase per capita. Data are extracted from Zhang and Niu (2013) based on a field survey in Gansu and Ningxia provinces.

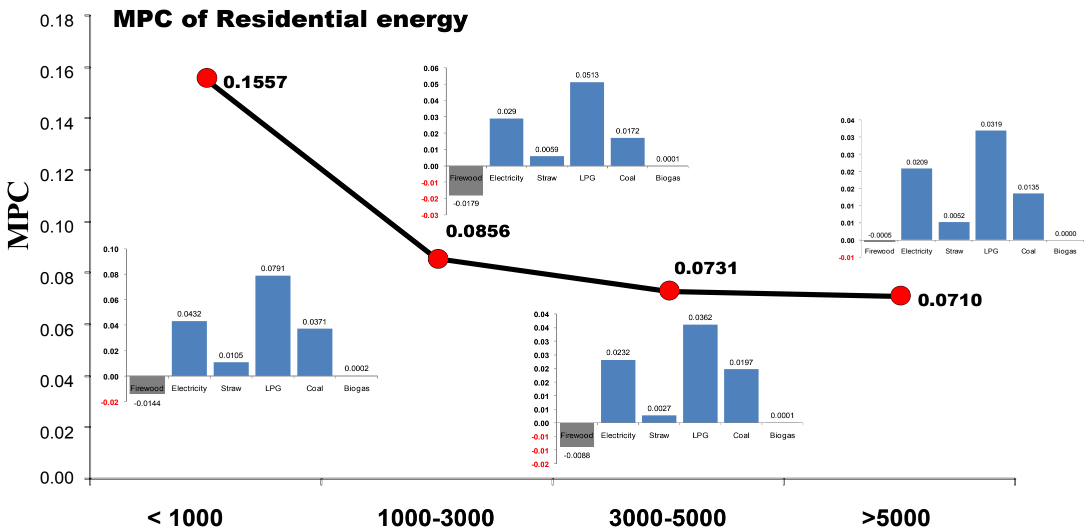

Figure 5.2 the marginal propensity to consume (MPC) of different fuels in among households with different income levels. The households are classified into four categories with per capita annual income at <1000, 1000-3000, 3000-5000, and >5000 RMB.

The indexes of economy, convenience, comfort and environment-friendly of different fuels differ obviously. Generally, LPG and electricity are expensive than biogas (economic index). Traditional biofuels like crop straw and wood are not as convenient as LPG and electricity (convenience index). The use of LPG, electricity and biogas is comfortable compared to the use of traditional solid fuels (comfort index). And, biogas, LPG and electricity are better for cleaner environmental quality than solid fuels (environmental index). For low-income residents, they may pay more attention to the economic cost of different fuels. With the increase of house income, the residents would prefer to use comfortable and environment-friendly fuels (Lu and Lu, 2006). It is noted that the household energy consumption structure may not change immediately after the increase of house income, particularly in low-income households. It is realized that with more house income, the priority choice of rural resident is not to change the fuels used in daily lives, only when the house income increased significantly, sometimes higher than a critical value, the residents would be willing to adopt new cleaner fuels for daily cooking and heating (Li *et al*., 2011).

4) Family size, gender and age. The family size, age and gender of members also have direct or indirect impacts on the fuel adoption. The old may be preferable to use traditional solid fuels (Wu *et al*., 2012; Wang *et al*., 2012). With a large family size, there would be enough labors for the development of some cleaner fuels like biogas. Because of the scale effect, the energy consumption per person usually decreases with the increased number of family member. In addition, the investigate study by Fei and Yu (2011) also showed that the female are more willing to change to the cleaner high-quality fuels in comparison with the male.

5.2 Knowledge and perception

The knowledge and awareness of the characteristics of cleaner fuels and perception of environmental protection and energy-saving affect the adoption behavior obviously. A field study in Fujian province found that the local residents are willing to adopt cleaner high-quality fuels, but they know little about these fuels (Liu *et al*., 2013). Wang *et al*., (2011) indicated that limited knowledge about cleaner fuels and stoves is an important barrier in the deployment and sustainable use. Only 72% households use fuel-saving stoves, of which 45% use for about 1-5 year and only 28% use the stove for more than 10 years.

Education level is an important factor affecting the knowledge and perception (Wu *et al*., 2012; Yang *et al*., 2009; Fei and Yu, 2011; Wang *et al*., 2012; Liang *et al*., 2012; Yu, 2007). In general, people with relatively high education level prefer to use cleaner high-quality fuels, and reduce the consumptions of traditional solid fuels. Based on a field survey in 9 provinces, Zhang *et al*., (2011) found that the chance of cleaner high-quality fuel adoption would increase by 0.66% with one more year education. Wu *et al*., (2012)'s study in rural Hebei found that the use of biogas increased significantly with the increase of education level. Yang *et al*., (2009) in Fujian also found that the household using solar energy positively correlated the residents' education level. However, in a study in Zhejiang and Shaanxi, Wu *et al*., (2012) reported an insignificant impact of education level on household energy choice. In their study, most significant factors affecting the household energy choice were income, year distribution of family member and livestock-breeding.

5.3 Fuel technology

The characteristics of fuel include fuel supply and price, convenience, and impacts on air quality in use. The importance of fuel characteristics affecting the adoption was mentioned in 24 studies. Lou *et al*., (2008) pointed out that in Sichuan the use of electricity is popular because of its convenience, cleanness, stable supply and the affordable price. The use of biogas can meet the household energy requirement and keep the environment clean, but without the policy and financial support from the government, the adoption willing of biogas may be low. In most area, especially remote areas, the cost of using natural gas is very high, thus very scarce use, meanwhile in these areas, coal is abundant and cheaper, and thus in wide use. Generally, low cost is the priority consideration of fuel choice. Residents prefer to use low cost, even free fuels. Beside the economic cost, the convenience of fuel use and benefits on air quality are also key factors in fuel choice consideration. LPG, electricity and biogas are convenient compared to coal, straw and wood. Also, these fuels produced much less pollutants than traditional solid fuels, that is, the adoption would benefit environment and human health, supporting the adoption behavior.

In addition to the fuel characteristics, the supply and development of corresponding stoves also influenced the adoption and sustainable use significantly. In a study in Nanjing, Jiangsu, it was found that the development and deployment of coal and LPG stoves may promote the use of coal and LPG, respectively, but the development of stoves using electricity did not have negative effects on the consumption of traditional fuels, which is thought to be due to the fact that electrical stoves are mainly used for preparing a meal while the coal stoves are mostly used to boil water. There is no significant cross-impact of stove on fuel usage.

5.4 Financial, tax and subsidy

As mentioned above, the cost (direct and indirect) of fuel affects the deployment obviously. It is expected that with the financial support from the local government, the deployment would be promoted and developed effectively. The practice in many rural areas showed that through the programs of national debt, public facilities grants, loan from world blank and so on (Tian, 2013; Mo *et al*., 2010), there is rapid development of cleaner fuels after the investment. Based on the results from field survey and the binary choice model, Chen and Zheng (2009) pointed out that because of the lack of financial investment, the utilization of cleaner renewable fuels would increase significantly with more financial support from the government. The quantitative study by Zhou *et al*., (2009) in Jiangsu and Jilin also found that the chance of biogas adoption would increase 49% if there are financial support and subsidy from the local government. In fact, to promote the development of biogas, the center government and ministries issued a series of financial support, tax and subsidy policy and started many programs in county and country. The investment on biogas development from the Chinese government was about 55.41 million RMB during the 9th five-year, 3.545 billion RMB during the 10th five-year, 20.2 billion RMB during the 11th five-year and near 4.4 billion in 2011. The investment on the development of straw gasification and compressed biofuels in 2012 was about 213.43 million.

5.5 Regulation, legislation and standards

There are 7 studies suggesting the importance of policy including macro-policy and detailed regulation, and legislation during the deployment of cleaner high-quality fuels (Tian, 2013; Mo *et al*., 2010; Li *et al*., 2011; Wu, 2012, Zhou *et al*., 2010; Zhou *et al*., 2009; Liu *et al*., 2013). In addition, there are 4 papers calling for the development of standards of cleaner fuel and stove (Tian, 2013; Zhao, 2007; Wu *et al*., 2007; Wang *et al*., 2011). It was realized that the shortcomings in the current energy policies included the lacking of detailed rules for implication, limited policies on financial support and economic incentive, the lacking of innovation in research and quality assurance, and limited policy guidance on residents' adoption behaviors. The development of rural energy, especially the deployment of cleaner renewable fuels is one key point in the Chinese national energy policy system. The center government and provinces issued a series of regulations and legislations. It is urgently required to make detailed implication rules in the local area, moreover, the rules should in line with the local conditions.

To control the qualities of fuels as well as corresponding stoves, so as to ensure the adoption and sustainable use, it is necessary to make a series of national/provincial standards on both fuels and stoves, like the measurement of stove thermal efficiency, biogas pool building technology, and the technical guideline and standards on the production of compressed biofuels. So far there are more than 70 standards covering the areas of the design of fuel-saving stove, the production and maintenance of cleaner fuels like biogas, biomass fuel, solar energy, and so on. These standards play important roles in the development of agricultural sector and household energy.

5.6 Market development

Industrialization of commercial cleaner energies and programs like CDM facilitate the development of rural energy in China. Tian (2013) analyzed that development status and future trend of Chinese rural energy, and pointed out that the development and industrialization process of biogas, biofuels and solar energy had achieved great success. Now in China, there are more than 5600 companies, of while these are hundreds of factories producing biogas stoves and accessories. The industrialization process has a very rapid development. Meanwhile, the CDM programs of rural biogas and cleaner biomass fuels and cookstoves also achieved successful results, and promoted the deployment of these fuels and cookstoves.

5.7 Management, publicity and demonstration

Without any doubt, the deployment of cleaner fuels and stoves, particularly new ones should be under the strong support of local government. With the emphasis of local government, especially the leader, the management, maintenance service and technical support will support and guarantee the fuel deployment. In addition to the emphasis from the local government, it is also very important and effective to give the publicity of cleaner fuels, and the adoption would be promoted after the demonstration from the around. Through the publicity and demonstration, the residents would have a deeper understanding of the new fuel and potential benefits after the adoption. Increased knowledge and perception of fuel-saving and environmental protection through the publicity and demonstration will generate the passions and enthusiasm.

5.8 Summary

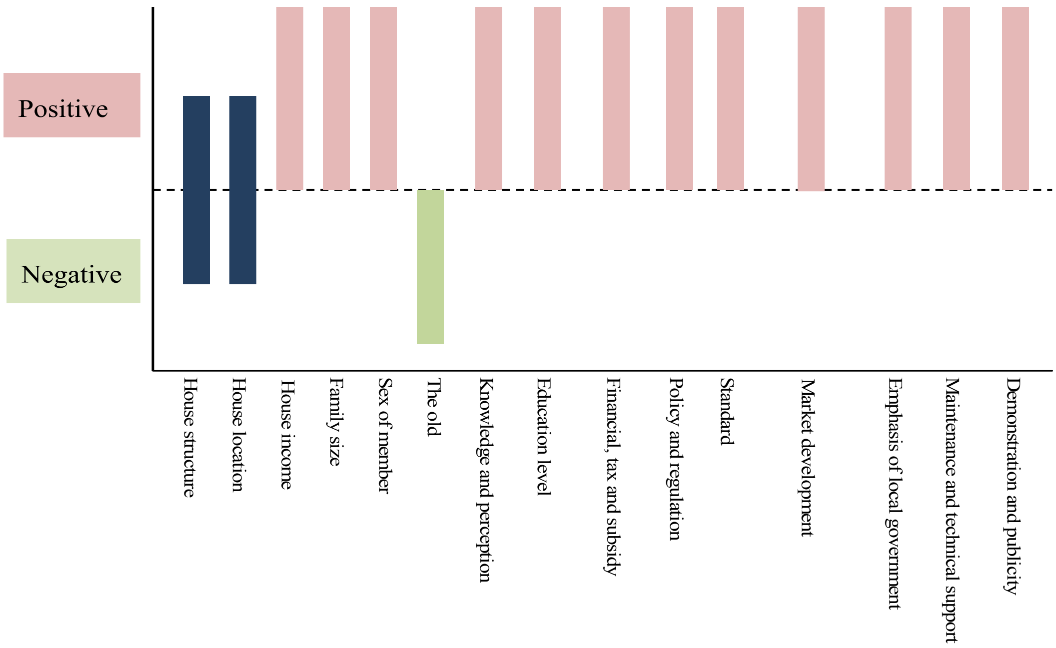

Figure 5.3 Summarized factors affecting the adoption of cleaner high-quality fuels

Table 5.1 Factors affecting the change of household energy consumption

Factor	Influence	How does it influence
Household structure	+ or -	Concrete structure household prefer to use cleaner fuels and cookstoves, related to the economic condition
Household location	+ or -	Related to the abundance, accessibility and cost of different fuels
House income	+	The chance of adoption increased after income increase
Family size	+	Large size with enough labor that is good for the development of biogas, and also would improve energy utilization efficiency due to

		scale effect
The female	+	The female prefer to adopt cleaner fuels
The old	-	The old are used to traditional fuels
Knowledge and perception	+	Knowledge and perception of new fuel characteristics and potential benefits would promote the adoption willing
Education level	+	With high education level, it is easier to accept new things
Tax and subsidy	+	To support the adoption and sustainable use
Policy and regulations	+	Detailed rules and regulations which are appropriate for the local conditions
Standards	+	To ensure the quality of both fuels and cookstoves
Market development	+	the development of fuel and stove market which would promote the adoption and guarantee the sustainable use
Emphasis	+	The emphasis of the government, especially the leader would support the deployment program in many aspects
Management and technical service	+	To support the sustainable and high efficient use of cleaner fuels and cookstoves
Publicity and demonstration	+	The publicity and demonstration will increase the adoption enthusiasm

Among the 87 peer-reviewed papers identified, over half studies analyzed the influencing factors in residents' fuel choice from traditional solid fuels to cleaner commercial ones like biogas, electricity, LPG. The total proportion of cleaner fuels is usually analyzed as a whole index in most studies.

The families living in concrete structure household prefer to use cleaner fuels which are thought to be related to the relatively high income compared with those in adobe and brick-wood structure household. The abundance and accessibility of fuels are determined, to a great extent, by the location. High price of cleaner fuels like LPG and natural gas in some remote areas may prevent their large scale deployment. The increase of house income would promote the change from traditional solid fuels to cleaner renewable fuels. The consumption of electricity is found to positively correlated with house income, while the consumption of biogas showed a positively correlation with income in low income period and a negative relationship in high income period which is explained by the fact that after a critical value of house income, the families using biogas would change to other cleaner renewable fuels like LPG. The size, age and gender distribution of family also affect the household energy consumption obviously. Generally, the old, the female and large size member families have more willing to adopt cleaner fuels.

The knowledge and perception of residents affect their adoption behaviors significantly. The increase of knowledge on fuel characteristics and potential benefits would be good for the deployment and sustainable use. The knowledge and perception is more or less affected by the education level, publicity and demonstration results.

Fuel characteristics including the economy, convenience, comfort and benefits for environment and human health are also important factors under consideration in the adoption process. For low income residents, the cost of fuel adoption is of prior concern, while for high income members, the convenience and comfort of cleaner new fuels are important.

To promote the deployment of cleaner fuels, regulations, legislation, detailed rules and standards are necessary. The market development would facilitate the adoption and sustainable use, and more important, guarantee the supply of cleaner fuel, corresponding cookstove and accessories. In addition, it should strengthen the role of local government. The deployment would achieve satisfied success under the emphasis and support of government, especially the leader, the technical service team and the publicity and demonstration of cleaner new fuels, which usually can increase the adoption enthusiasm.

6. Factors affecting biofuel development

China is abundant of biomass fuels including crop straw, woody materials, plants and so on. It is estimated that the yield of crop straw in China is about 600 million tones, among which approximate 300 million tones can be used as the energy fuel. The available amount of woody material was about 900 million tones, and among it there was about 300 million tones can be used as the energy fuel. As such, the biomass fuel in China being used as the residential energy is about 500 million tones equivalent coal (tec), and would be about 1000 million in the coming years with the increased area of tree planting. The high efficient utilization of biomass fuels is of high importance in China, and the development of biogas, biomass briquettes and straw gasification are of priori consideration.

6.1 Biogas

As a cleaner fuel, the deployment of biogas has great perspective in China. By 2005, there were over 1.8 million households using biogas, and the annual yield of biogas was about 7 billion m^3. In the present study, we found 35 studies analyzing the key influencing factors in the deployment and sustainable use of biogas. Among them, 6 studies conducted qualitative analysis based on the results from field questionnaires and interview, and 6 did quantitative analysis by using models like Probit, Logit analysis and binary choice model (Figure 6.1). The influencing factors affecting the biogas uptake include household location, house income, knowledge and perception, the supply and quality of raw material and gas, the policy and financial support from the government, and so on.

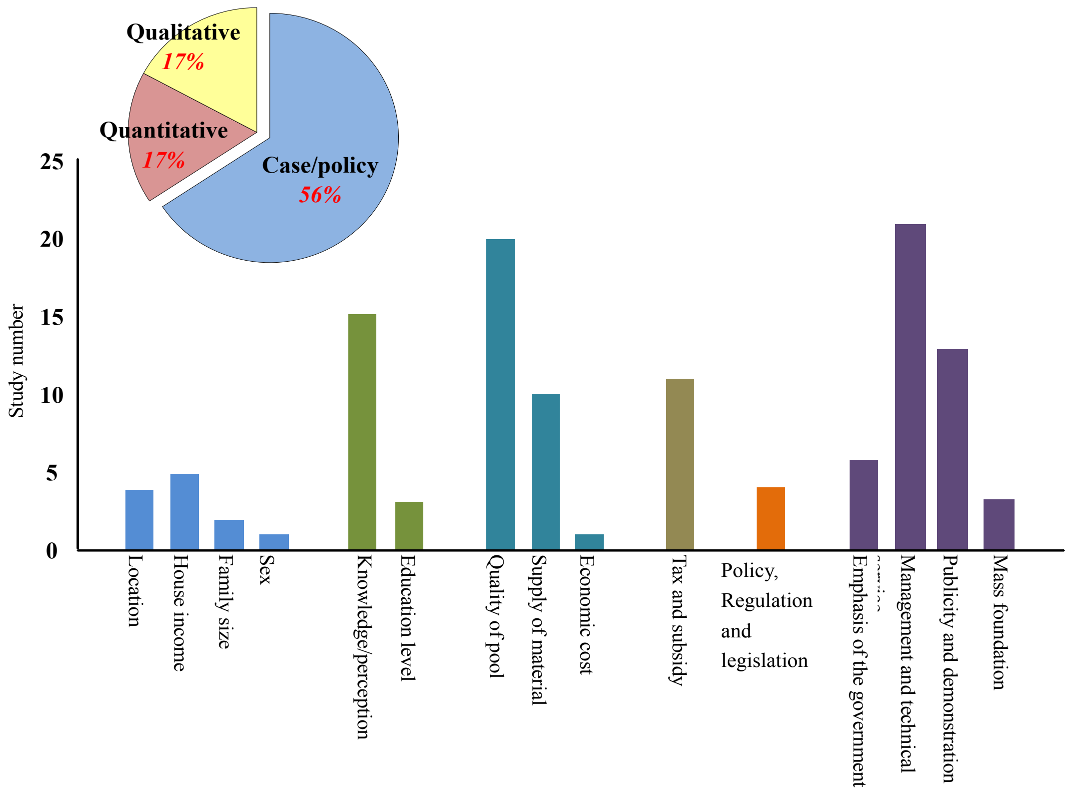

Figure 6.1 Mentioned times of various factors affecting the adoption and sustainable use of biogas

6.1.1 Household characteristics

1) Location. The location of household, family size, the age and gender of family member, and house income are factors found to affect the adoption of biogas. The yield of biogas is highly influenced by the local climate conditions. Generally, the yield was positively correlated with local temperature (Wang *et al*., 2007), thus, the development of biogas may be only suitable in some areas with comfort natural conditions. Chen *et al*., (2009) pointed out that areas with 7-12 months having an average ground temperature (1.6 m height) higher than 10 ^{0}C are good for the development of biogas, areas with only 6 months having the ground temperature higher than 10 ^{0}C but having abundant solar energy are also suitable for the biogas development, while areas with less than 6 months having the ground temperature higher than 10 ^{0}C and lacking of enough solar energy resource might be not suitable for the development of biogas.

2) Income. In term of the influence of house income, Lu and Liu (2006) found that households with home income per capita higher than 4000 RMB are preferable to use LPG, while those with per capita income less than 4000 RMB, the biogas is their prior choice if available, otherwise, they have to use traditional solid fuels like firewood and coal. It is found that in low income household, the residents are willing to adopt biogas, but in most high income household, they may tend to use cleaner fuels like LPG other than biogas if the problems of gas supply, maintenance of pool, and relatively short usage of biogas cannot be solved (Yang, 2011; Wang *et al*., 2007; Wang and Xin, 2007). By using the maximum likelihood regression analysis, Cui and Wang (2009) reported that the chance of biogas use will decrease 19% with per 1000 RMB increase of house income. This is because after the increase of house income, most residents would prefer to use cleaner fuels like LPG other than biogas. As mentioned above, only for the low income residents who mainly used traditional solid fuels for cooking and heating, the increase of house income may promote the shift of traditional fuels to biogas. The turning point in such quadratic curve of house income-biogas usage relationship may vary in different areas.

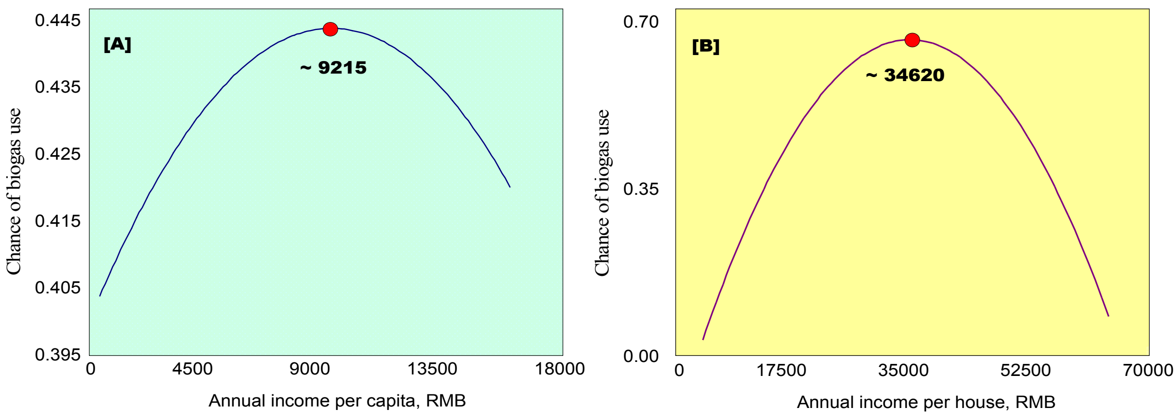

Figure 6.2 the chance of biogas adoption with the increase of annual revenue per capita (left panel using data from Zhou *et al*., 2009), or annual income per household (right panel using data extracted from Wu *et al*., 2012).

3) Family size, age and gender. The influence of family size is mainly because the build and maintenance of biogas pool require extra labor. With many rural residents migrated into the urban area, and more and more residents went out for work, the maintenance of the biogas pool became a main barrier in the sustainable use of biogas. With much less labor in home, many households gave up the use of biogas (Liu and Jia, 2011; Cui and Wang, 2009). The study by Cui and Wang (2009) found that the chance of biogas use will decrease by 3.8% if the population going out for work increased 1%. Based on the field questionnaires and Logit analysis, Zhu and Zhao (2012) found that the female prefer to adopt biogas, and the old may be used to consume traditional solid fuels.

6.1.2 Knowledge and perception

The knowledge and awareness of biogas and potential benefits after use influence the adoption behaviors significantly. Among the papers analyzing influencing factors of biogas adoption, 51% indicated the importance of knowledge and perception on biogas adoption. Lacking of awareness is one important barrier preventing the biogas adoption and sustainable use. In most area, the awareness of biogas is still limited to the use for cooking, and the other usage of biogas and the utilization of biogas residue are not well known. In addition to the awareness of biogas characteristics and utilization ways, the perception of fuel-saving, environmental protection and human health protection also influenced the decision to adopt biogas (Zhu and Zhao, 2012).

The knowledge and awareness of biogas, to some extent, is related to the educational level. It is in general that people with higher education level is easier to adopt new thing. Cui and Wang (2009) reported that the adoption willing of new cleaner fuels is higher in residents with higher education levels, moreover, these high education population are the young group who can act as essential labors for the building and maintenance of biogas generating pool. They found that the chance of biogas use increase 10% when the accepted education level increased 1 year. However, in another analysis by Wang *et al*., (2007) based on the national statistical data, it is found that the influence of education level on biogas uptake is not significant, which was explained by the fact that the biogas technology is not new in China, and most residents in rural area can use the biogas stove, and even in some area, those who often operate and maintain the biogas pool are adults with large ages and low education levels. The difference between these two studies is thought to be due to a large number of populations going out for work after the receiving of high education. The education level in Wang *et al*., (2007)'s study based on the national statistical data can not reflect the education level of groups living in the rural area. In summary, with the spreading of education in China, many people will go out for work outside or migrate into urban area after the receiving of high level education, which would result in the lack of labor in the build and maintenance of biogas pool and subsequently un-favor for the development of biogas. On the other hand, higher education residents living in rural area will be easier to accept new things and adopt biogas from the use of traditional solid fuels.

6.1.3 Fuel characteristics

The quality of biogas, continuous supply of raw material and gas, the quality and safe of biogas generating pool are factors of fuel characteristics affecting the adoption and sustainable use. Among identified studies, about 89% (30 ones) indicated the importance of fuel quality and continuous supply. Wang *et al*., (2005) showed that among various factors affecting biogas uptake, the most important ones were the biogas production rate, the price of alternative fuel like coal, the cost in pool building and raw material supply. Nowadays, the construction techniques of biogas pool are very simple. Low quality of pool is a key barrier affecting the sustainable use of biogas. Technical guideline must be made to ensure the quality of biogas generating pool. Another reason in the abandon of biogas is the lack of continuous supply of raw material, which directly affects the biogas production rate. Both studies by Zhu and

Zhao (2012) using field questionnaire results and Wang and Xin (2007) based on the data from statistical yearbook showed that the chance of biogas use in household with livestock farming was higher than those without livestock. With the decrease in livestock farming in most rural area which is related to the fact that many labors went out for work outside and the price of feed increased, the supply of raw material is an important problem for most residents in the development of biogas. Some areas are trying to use crop straw in the biogas production, but the alternative raw materials may face problems like difficulty in tap, acidification or basification of fermentation broth which affected the production rate and quality of biogas (Li *et al*., 2007; Gao, 2011).

6.1.4 Tax and subsidy

Cost is needed to build and maintain the biogas generating pool. In most cases, the building of pool is supported financially by the local government, and the self-investment from the resident is very limited (Zhou *et al*., 2013). The financial support from the governmental is an important enabler in the development of biogas. The real practice showed that the lack of special funds and subsidies is one main reason causing the abandon of biogas in many areas. However, it is noted that only financial support from the local government is not sustainable. To promote the adoption and moreover to ensure the sustainable development of biogas, some areas developed the biogas program through the combined system of “subsidy from the center government, special funds from the local government and self-financing”. These programs often resulted in satisfied outcomes (Kang, 2009). Hu *et al*., (2008) reported that in Suining, Sichuan province, biogas is the main energy used for cooking (91%), bathing (32%), lighting (33%) and fat storage (27%), and more important, over 90% households are still using the biogas long after the adoption. In the area, only 23% household biogas pool was totally supported by the government, and there was 36% built by the residents themselves, and 41% households built the biogas generating pool under the combined support from government and self-financing. Zhu and Zhao (2012) reported that the external funds were negatively correlated with the adoption willing, which might be explained by the fact that most residents are not ready to afford the national debt in order to switch traditional fuels to biogas. Thus, to promote the development of biogas, the financial support from the government should be in the form of special funds and subsidies instead of national debt.

6.1.5 Planning and policy

The planning, regulation and legislations that support and guide the development of biogas are important external factors (Kang, 2009; Zhou and Shu, 2007; Cui and Wang, 2009; Hu *et al*., 2008). The practice from Enshi county in Hunan province and Bayanzhuoer county in Inner Mongolia province suggests that a good plan and the guide of government under detailed regulations and rules are important factors in the development of biogas. In the planning and regulations, it is essential to form a profession technical service team. Also, the development of biogas should be combined well with other program and polices like the development of livestock industry and agriculture, the project of farm-city market basket program, and the creation of livable and healthy cities in China. It is also needed to consider the treatment of fermentation broth, which may be treated together with the organic waste water. The policy and detailed rules of biogas utilization vary in different areas. Different comprehensive utilization models can be under consideration and encouraged in real practice.

6.1.6 Management, publicity and demonstration

The emphasis of government, the management and service level of a professional team, and the publicity and demonstration effects can promote the adoption behavior. There are 6 papers raising the importance of governmental emphasis, 21 studies suggesting the need to improve management and service ability by establishing a professional technical team, and 16 studies highlighting the role of publicity and demonstration.

Without doubt, the emphasis of the local government, particular the leader in China is very important enabler for the deployment. Not only the policy and financial support became available under the emphasis, the professional technical team and market development that are required in the sustainable use of biogas after the adoption also need the support from the local government and officers. The building and maintenance of biogas generating pool require a professional team so as to ensure the quality of both pool and generated biogas. Whether there is a technical service team affects the residents' adoption obviously. Without technical support, the problems occurring in the use of biogas can not be solved in time, which subsequently would reduce chance in the sustainable use of biogas.

Meanwhile, it is necessary to give the publicity of biogas so that the residents can know better about the characterization of biogas and also the benefits on environment and human health after the adoption, which would increase their adoption willing and enthusiasm. The demonstration from the around would set good examples of biogas utilization which can increase confidence in biogas adoption and bring the others participating into the adoption group.

6.1.7 Summary

Many external and internal factors can affect the adoption and sustainable use of biogas. The emphasis of government, a good planning, detailed rules and regulations beneficial to developing biogas, and a profession technical service team are all enablers to promote the development of biogas. By giving the publicity of biogas and demonstration of biogas utilization from the around, the knowledge and awareness of biogas and potential benefits after adoption would increase, and the confidence and enthusiasm will be inspired which would facilitate the adoption and sustainable use of biogas.

Financial support from the external is essential for the biogas deployment, but to ensure the sustainable use of biogas, a combination of governmental funds and self-financing may be a better choice. The financial support from the government should be in the form of special funds and subsides instead of debts since most residents are not willing to afford a debt in order to use biogas.

The production rate and quality of biogas affect the adoption and sustainable use significantly. The development of biogas can be facilitated in some areas with favorable ground temperature and solar energy resource. The adoption willing may be higher in households with livestock feeding since it can get raw materials from the livestock.

House income, family size, the age, gender and education level of family member, all affect the adoption behaviors directly or indirectly. In general, with the increase of income, the household used to consume traditional solid fuel will switch to biogas, but when the income continued to grow, they may switch to other cleaner fuels like LPG. Thus the influence of house income on biogas deployment might be either negative or positive depending on the house income level. The turning point varies in different areas. More populations go out for work outside will result in insufficient labor in the building and maintenance of biogas pool, thus unfavorable for the development of biogas in the area. The female in home are more willing to adopt biogas since they conducted the fuel burning activity and exposed directly to pollutants emitted directly in most time. With higher educational level, it is easier to accept new thing. So, it is expected that the deployment of biogas would be push forward with more people at home receiving higher education levels. It should be noted that the adoption can be promoted only when the education level of residents at home increased. A number of people go out for work after receiving of higher education will reduce labor in biogas pool maintenance, which as a result is not good for the sustainable use of biogas.

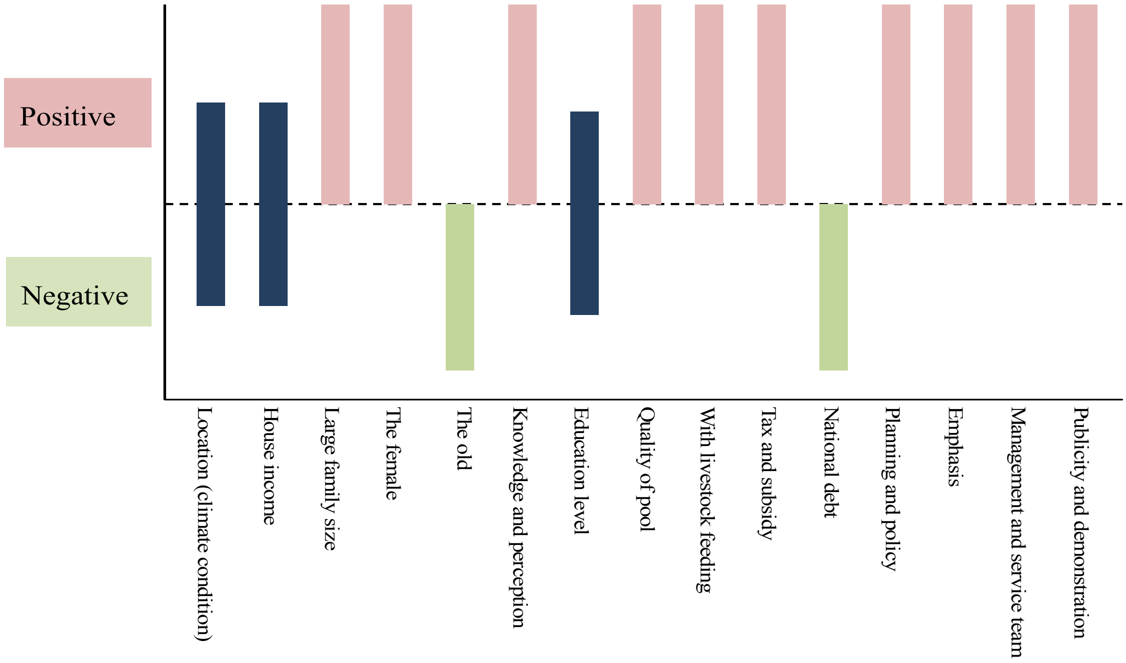

Figure 6.3 Factors affecting the uptake of biogas

Figure 6.3 summarized quantitative results of biogas adoption influencing factors. The *odd* values larger than 1.0 suggest a positive influence. It can be found that the ground temperature has a positive impact on biogas uptake, while in the breadbasket area the development of biogas may be difficult because of abundant of biomass fuels. In the area where LPG was widely used, the deployment of biogas may also result unsuccessful results. The awareness of environmental protection, strong support and financial invective from local government, training courses and participate into association have positive impacts on biogas uptake.

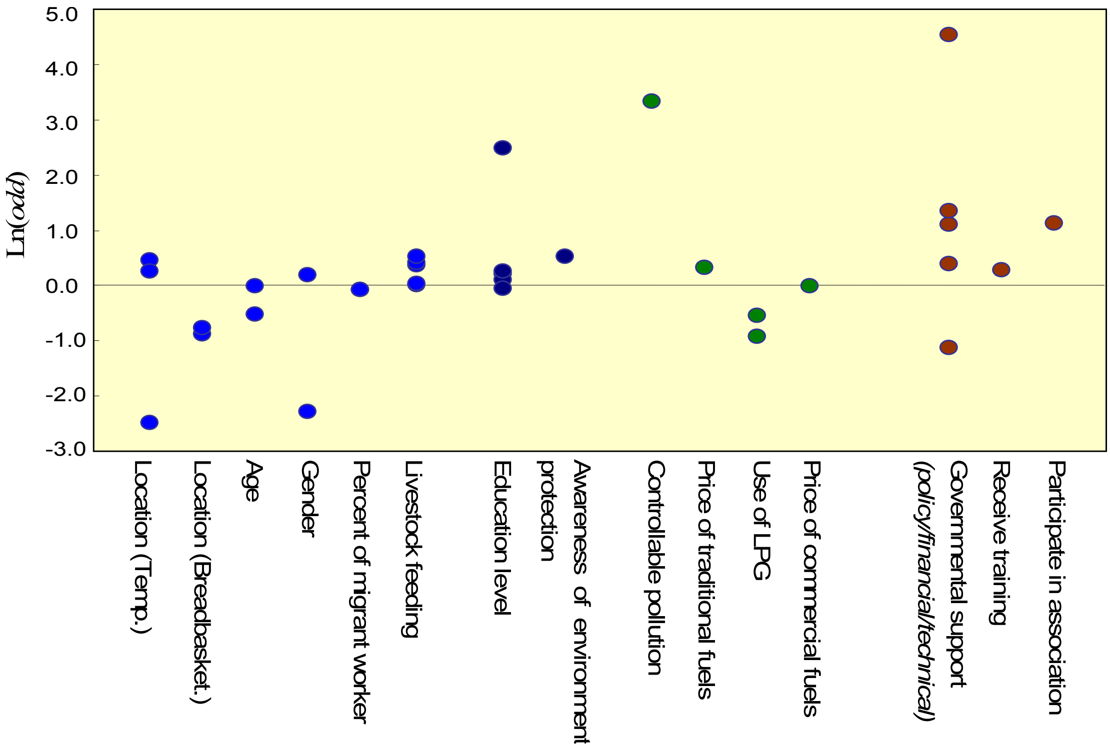

Figure 6.3 the influence of various factors (excluding income) affecting biogas adoption. Data shown are extracted *odd* values for different influencing factors identified in quantitative studies in Chinese literatures.

Table 6.1 Factors affecting the adoption and sustainable use of biogas

Factor	Influence	How does it influence?
Location (climate condition)	+ or -	Abundant solar energy resource and with at least 6 months having the ground temperature (1.6 m) higher than 10 ^{o}C
House income	+ or -	For low income households, increase of house income promote the switch to biogas from traditional solid fuels, but for high income households, the residents may switch to use LPG after the increase of house income
Family size	+	Without enough labors to build and maintain the biogas generating pool, small family size is not good for biogas development
The female	+	The female prefer to adopt biogas
The old	-	The old are used to burn traditional solid fuels
Knowledge and perception	+	Increased awareness and more knowledge of biogas and potential benefits may promote the adoption
Education level	+ or -	Higher education groups are easier to accept new things, which is good for biogas development. But, with more people going out for work after receiving higher education, the lack of labor for pool maintenance is not good for sustainable use

Pool quality	+	Simple construction technology and poor quality of pool result in wide abandon of biogas
Livestock feeding	+	Livestock feeding can guarantee the supply of raw material for biogas production
Tax and subsidies	+	Special funds and subsides in the building of pool and development of biogas
National debt	-	Most residents are not willing to afford debt in order to use biogas
Planning and policy	+	Beneficial planning and policy, and detailed rules and regulations can promote and ensure the deployment and sustainable use
Emphasis	+	The emphasis of government, particular the leader is of prior importance in China
Management and service team	+	A professional technical team that can solve problems in time and guarantee the sustainable use
Publicity and demonstration	+	Good publicity and demonstration effects increase the adoption confidence and enthusiasm

6.2 Straw gasification

To increase the comprehensive utilization efficiency of agricultural waste, to reduce the pollution induced by the agricultural waste, and also to improve the life quality of rural residents, the Chinese started to explore the use of straw gasification in rural area. After about ten years' efforts, there were more than one thousand gasification stations built by the local government during the 1990s. Through the pyrolysis and gasification processes, the utilization efficiency increases significantly after the straw gasification. Generally, the efficiency of direct burning of straw is 15-20%, but the efficiency can be high as 35% in gasification.

After the deployment of straw gasification, the cooking behaviors were found to be changed obviously after more free labor and less cooking time. With less incomplete pollutants emitted, the air quality is also improved significantly. In addition to the environmental benefit, the development of straw gasification can result in obvious economic benefits compared to the use of traditional raw straws. However, it is also noted that a variety of problems existing in the deployment and sustainable use of the straw gasification, like the quality and sate use of gas and gasification satiation, and the cost of operating a satiation.

In Xuzhou, Jiangsu Province, straw gasification has been developed for a long time and achieved satisfied results since the economic conditions in the area are generally better than the other rural areas in China (Wang, 2005), moreover, the centralized distribution of rural households (very close to each other) is good for the development of large scale straw gasification. To ensure the sustainable use, it is suggested that the commercial market should be developed. Yin *et al*., (2012) pointed out that the development of straw gasification needs a large number of money investment and most of the current use is in the period of demonstration. This requires more efforts in strengthening in governmental management, training of facility use and maintenance, and efforts to develop good systems on the management of gasification station.

Table 6.2 Factors affecting the uptake of straw gasification

	Factor	How do the factor influence?
1	Gas quality	To solve the problem of low heating value and high tar content
2	Financial investment	Large investment in building the station
3	Market development	To form professional company and technical teams in charge of gas production and consumption
4	Regulation and standard	Regulation, legislation and standards on the quality of gas and gasification station
5	Management	Strengthen the governmental management, promote the demonstration, and develop good management systems on gasification station

6.3 Compressed biofuels

Compressed biofuels (briquette or pellet) as an alternative for high efficient application of biomass fuels have arisen more and more attentions. Compressed biofuels usually have low densities and easier for transport and storage compared with the raw material. The burning efficiency of compressed biofuels is generally higher than that for the raw material, and subsequent, lower incomplete combustion pollutants emitted. In China, the use of compressed biofuels is still in the pilot. Among the 87 identified studies, 3 papers analyzed that status, problems and suggested countermeasures in the deployment of compressed biofuels in China (Liu, 2007; Ma *et al*., 2010; Yang *et al*., 2006). Yang *et al*., (2006) discussed the status and problems in the development of straw briquetting technologies and large scale production. Liu (2007) and Ma *et al*., (2010) analyzed the problems in the deployment of compressed biofuels and main influencing factors based on the results from questionnaires and interview.

Yang *et al*., (2006) pointed out that the adoption and sustainable use of compressed biofuels may face the barriers of 1) investment foundation and prices of fuel and fuel materials, 2) management, 3) favorable policy and tax, and 4) publicity and awareness of the relatively new fuel types. Most residents can not afford relatively high price of compressed fuels. The operation and maintenance of compressing machines lacks professional teams. And so far, there is no good policy and economic incentive systems which are favor for the large scale deployment of compressed biofuels. Also, the publicity and awareness of these relatively new fuels is still very limited which to some extent prevent the residents' adoption.

Based on the field survey results, Liu *et al*., (2007) found that the collection and pre-treatment of raw materials for the production of compressed biofuels are important factors affecting the large scale uptake of compressed biofuels. The mechanization of material collection would be sped up. The price and availability of alternative fuels influence the choice of compressed fuels obviously. About 45% residents are willing to consider use compressed biofuels only when the price of coal is higher than that of compressed biofuels. They also suggested that the technology and cost of compressed fuels are key factors affecting the deployment. With the improvement of technology and subsequent higher production and lower cost, which should be in the affordable range of rural residents, the large scale uptake of compressed biofuels would be achieved. The study by Ma *et al*., (2010) in Henan area also showed that factors affecting the adoption of compressed fuels included the collection of raw materials, the price of compressed biofuels and alternative fuels (about 72% residents may chose to use the compressed biofuels when the price is lower than coal), the financial and policy support from the local government, and the awareness and perception of environmental protection and benefits after the fuel deployment.

Thus, it can be found that factors affecting the adoption of compressed biofuels in household include the perception of residents, household income, the continuous supply of compressed biofuels, the price of fuel and alternative fuels, policy, tax and subsidy favor for the deployment of compressed biofuels, and the publicity and demonstration of these relatively new fuel types.

Table 6.3 Factors affecting the deployment of compressed biofuels

	Factor	How does it influence?
1	Household income	Increase the household incoming so that the residents can afford the new fuels
2	Knowledge and perception	Awareness of energy-saving and environmental protection would promote adoption
3	Fuel technology	Include the supply of raw material, the production of compressed biofuels, the price of compressed biofuels and alternative fuels
4	Favorable policy	Detailed, operable policies should be conducted to promote the development of fuels and stoves
5	Tax and subsidy	Effective economic incentive should be given to the fuel production companies and fuel use residents
6	Management	Emphasis of local government and leaders, publicity and demonstration of new fuels

7. Summary and research needs

7.1 Influence factors

Residential combustions of traditional solid fuels like crop straw, firewood and coals, usually have low efficiency, high pollutant emission and subsequently affect the air quality and human health significantly. The pollutant emissions also influence the local/regional climate change and social-economic development directly or indirectly. The deployment of cleaner fuels and cookstoves is good for environmental protection and human health. The present study based on a systematic search of Chinese peer-reviewed literatures, analyzed factors affecting the adoption and sustainable use of cleaner fuels and cookstoves in China. These influencing factors are either subjective or objective. Key influencing factors include the fuel and stove technologies like thermal efficiency and convenience; the regulation, legislation and standards; the development of stove and accessory market; financial, tax and subsidy support; the knowledge and perception of environmental protection, fuel-saving and also characteristics of fuel/stove, and more important, the emphasis of local government, particularly the leader and publicity and demonstration of relatively new cleaner fuels and stoves.

7.1.1 Development and influencing factors on stove uptake

The development of household stove in China can be classified into four stages: 1) initial stage before 1980, 2) improvement and deployment stage between 1980s and mid 1990s, 3) technical innovation between late 1990s and 2005, and 4) accelerated development stage after 2005.

In the late 1990s, the deployment of improved fuel-saving stoves achieved very slow progress, and the main reason was that the adoption of these stoves is lopsided on thermal efficiency without enough emphasis on the practicably. The problems included that 1) stove door was so small that which only small branches or straw can be inserted, 2) stove chamber was so small that fuels had to be inserted into the chamber in many times and the operator can not leave during the combustion processes, 3) complex flue pine that can easily stick down smoke and require a clean maintenance, 4) not convenient in use especially when it is necessary to boil water and cook food.

Some straw gasification stoves came into use between the late 1990 and early 2000s. These stoves connected the gasification furnace and stove directly, but because the gasification conditions can not be controlled and the supply and quality of gas vary dramatically which results in problems in stove adoption and safe use. It needs to treat tar, waste water and CO pollution in the use of this type of stove. Therefore, the stove should not be under large scale deployment before the development of technology. Another type of typical innovated stove is high efficiency low emission stoves, which have the secondary air supply from the top beside the primary air supply from the bottom. It is generally accepted that stoves with the following characteristics can be classified as "high efficient low emission stove"-*thermal efficiency*: > 35% for a cooking stove, > 60% for a cooking and heating stove and > 65% for a heating stove; *smoke emission:* < 50 mg/m^3, *SO_2, NOx and CO emissions*: <30 mg/m^3, <150 mg/m^3, and < 0.2%, respectively.

Factors affecting the uptake and sustainable use of stove include the stove technology such as thermal efficiency and operation convenience, regulation, legislation and standards on stove and accessories, market development, financial support include tax and subsidies, the awareness and knowledge on stove and environmental protection, as well as the effects of publicity and demonstration. With rapid increase in stove factories and companies, the production ability of some stove companies can reach 30 thousands per year. The R&D of stove technology has be facilitated, and with more international cooperation and communication, the fast and large scale deployment of cleaner stoves for cooking and/or heating could be expected.

7.1.2 Factors affecting cleaner fuel adoption

The adoption and sustainable use of cleaner fuels could be affected by a variety of factors. Usually, residents living in concrete households prefer to use cleaner fuels like electricity, LPG and solar energy, which is associated with their relatively high income level. In the remote area, the higher price of cleaner commercial fuels prevents the adoption and sustainable use. So, in addition to the external influence of location, the increase of household income is an effective way towards the choice of cleaner high quality fuels. The family size, age and gender of family member also affected the adoption of cleaner fuels. It is widely accepted that the knowledge and perception of residents and the awareness of fuel characteristics and environmental protection influenced the adoption behaviors significantly. The emphasis of local government is very important, not only in China but also other developing countries. Under the emphasis, the good management systems and professional technical support teams can be available. Also, it is essential and important to make regulation, legislation and tax and subsidy that are favorable for the development of cleaner fuels and stoves. The market development of commercial fuel and stove is necessary.

About biogas, it is important to have a good planning and make support policies and detailed measures favorable for the development of biogas with the emphasis of local government. The deployment and sustainable use of biogas require the guarantee of high quality biogas generating pool, and a professional operation and maintenance technical team. To give the publicity of biogas characteristics and benefits after the adoption, and increase the residents' awareness through the publicity and demonstration from the around would be good for the biogas deployment. In the development of biogas, it is once mentioned that the financial support from the government should be in the form of subsidy instead of national debt, since most residents are not used to afford a debt in the daily lives. The combination of governmental subsidy and self-financing may be a choice for the sustainable development of biogas in rural area.

In term of straw gasification which came into view from the 1980s, there were several thousands of gasification stations built under the sponsor of local government. The deployment of straw gasification achieved successful social, economical as well as environmental outcomes, but also faced problems like the quality of gas and gas station, the safe use of gas, and relatively high cost in the operation and maintenance of station. It was identified that key factors affecting the deployment and sustainable use of straw gasification included the quality of gas (heating value and tar content), financial investment, market development, the development of standards on gas and station quality, and the management and service of government (emphasis, publicity and demonstration).

Factors affecting the adoption and sustainable use of compressed biofuels include residents' knowledge and perception, house income, the supply of raw material, the price of compressed biofuels and alternative fuels, policy and regulations supporting the fuel use, tax and subsidy, emphasis of the government and the publicity and use demonstration. It would facilitate the adoption and sustainable use with the increase of house income and giving the publicity of fuel characteristics. As a new fuel type in pilot nowadays, there is an urgent need to conduct more researches on the briquetting technologies and stoves that go with the compressed biofuels. Detailed rules and regulations, financial, tax and subsidy supports are needed to ensure the continuous supply of raw material. With the development of market, the deployment of compressed biofuels is expected to be promoted with decreased cost.

Thus so, factors affecting the adoption and sustainable use of cleaner fuels can be summarized as following:

1) Fuel/stove technology. The burning and thermal efficiency, continuous supply, convenience and cost are critical factors affecting fuel adoption. For low income household, the cost of fuel is of prior concern, while for high income household, the convenience, comfort and benefits on environmental quality and human health are considered in the fuel choice. For biogas, the supply of raw material, the quality of biogas generating pool and the quality of biogas affect its use significantly.

2) Household and setting characteristics, including factors like family size, age, gender, household income, location and structure. Without doubt, the house income affects the adoption behavior significantly. With the increase of house income, it is possible for most residents to adopt cleaner commercial fuels so as to improve the living conditions. The consumption of biogas increases with the income increase at the very beginning, and after a critical value of house income, the biogas consumption decreased with the income increase. Most residents would change to other cleaner and renewable fuels like LPG. The peak value varies in different areas. The location and structure of household are also found to correlate with the fuel choice in some area. In families with concrete structure, people prefer to use cleaner commercial fuel, which is related to the relatively high income of the household. The influence of location is related to the abundance, accessibility and cost of different fuels. In most remote area, the commercial fuels like natural gas and LPG are expensive in comparison with nearly free biomass fuels and cheap coals. The development of biogas is also determined by the local conditions like ground temperature and solar energy resources. In terms of the size, age and gender of family members, the young prefer to use cleaner high-quality fuels while the old are used to traditional solid fuels in daily cooking and heating. Because of the scale effect, the fuel utilization efficiency is generally higher in large size family (4-5 members) compared to the family with less than 3 persons. In addition, with more people in home, there would be enough labors to use and maintenance the biogas pool so as to continuously support the biogas fuel. Compared to the male in family, the female are preferably to adopt cleaner new fuels since they, in most cases, conducted the cooking and heating activities in home, and thus expose directly to incomplete pollutants emitted from the domestic burning. Besides, changing to cleaner fuels with relatively high burning efficiency would reduce the total time spent, decrease fuel consumption amount and free the labor to do other works which additionally increased the house income.

3) Knowledge and perception. The knowledge and awareness about fuel characterization and potential benefits after adoption of residents are positively correlated with their adoption willing and enthusiasm. Through the publicity of new fuels and cookstoves, and through the demonstration from the around, there would be more and more residents know about these new fuels and cookstoves, and would participate into the adoption group. Generally, with a higher education level, it is easier to adopt new things, which means to use cleaner fuels and cookstoves in the present study. The education is spreading in China, which is good for the deployment. But it is also realized that more rural residents go to look for work elsewhere and migrate into the urban and big cities after graduation which to some extent is a limiting factor for the development of biogas in rural area since it requires relatively large labor to maintenance the gas production.

4) Policy and regulations. The adoption would be promoted under the support of beneficiary macro-policy, detailed regulations and rules, It is important to decide distinct rules and regulations to different areas.

5) Financial support. Through the ways of low tax and subsidy, financial support from the government would increase the adoption willing and more important at the very beginning facilitate the adoption behavior without the increase of residents' financial burden.

6) Market development. It is important to guaranteeing the sustainable use of cleaner fuels and stoves after the adoption with a good development of fuel, stove as well as stove accessory market. The beneficiary policy will also facilitate the market development.

7) Governmental support. The role of government is in particular important. The publicity, demonstration and after-sale services would increase the enthusiasm and willing in adoption. With the emphasis of government officers, a professional team would guarantee the service and technical support.

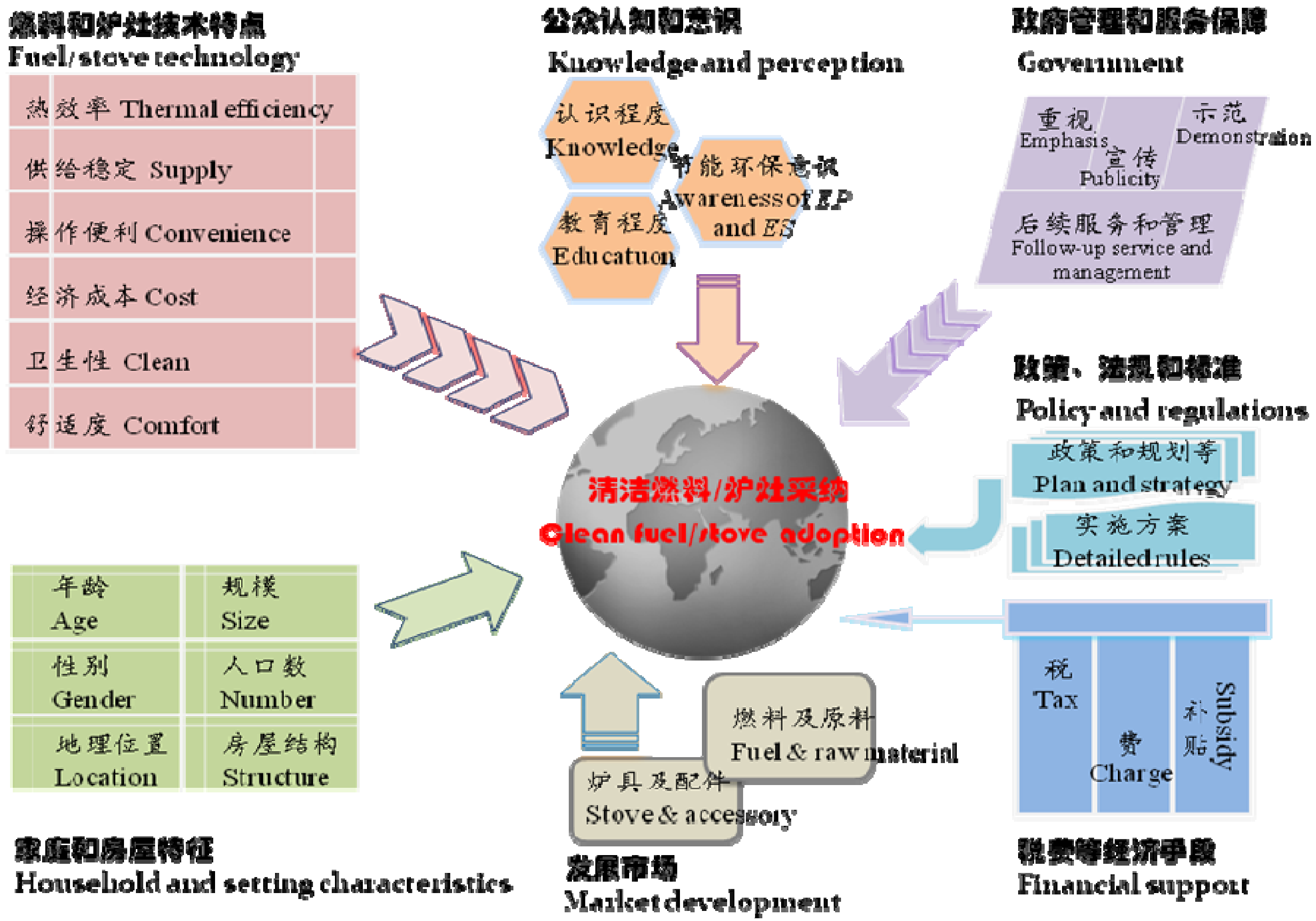

Figure 7.1 Factors affecting the adoption and sustainable use of cleaner fuels

7.2 Research needs

1) Studies on factors affecting adoption and evaluation of relative importance of different factors are still limited.

After this literature review, we note there are some studies focusing on the factors affecting the uptake and sustainable use of cleaner fuels and stoves in China. However, such studies are still very limited, particular lacking of qualitative/quantitative studies based on the field survey and interpreted and explored the collected data with appropriate analysis models. So, more field studies are urgently required to identify key factors influencing the residents' adoption behaviors and how to ensure the sustainable use. Among a variety of cleaner high-quality fuels, the adoption of biogas is more concerned than the adoption of other fuels. In addition, factors affecting the adoption of cleaner cookstoves, or high efficient low emission improved stoves, are rarely studies. These should be paid attention in future study.

Although some enablers and barriers were identified, it is realized that it is very difficult to identify the relative importance of these factors. It is hard to answer which factor is the most significant factor that should be paid more attention in the deployment campaign, even though this may vary in different areas. The temporal and spatial variance in the influence of these factors should be taken into consideration in the future study.

2) The spatial and temporal variations of different fuel/stove combination in use are unclear.

Nowadays, a variety of fuels and stoves come out. These stoves may be different only in the outlook, or optimized in both burning chamber design and outlook. It is necessary to investigate the situation of these fuel/stove combination in field, including how much are used, the change in fuel consumption and pollutant emission before and after adoption, and also the convenience and feedback from the user. Because of large variations in economical conditions in China, the adoption of cleaner fuels and stoves differs significantly among different areas, and also key enablers or barriers may be different from site to site. The temporal and spatial variations should be taken into further consideration.

3) Very few study on the test standards, real thermal efficiency and pollutant emission in laboratory or field.

It appears that there is only a brief definition of high efficiency low emission stove now. In practice, it is hard to decide which stove can be classified as improved stove or *kang*. It is also noted that there are some differences in standard test methods between China and others like American test methods. How would such difference affect the evaluation of cookstove quality is unclear. In addition, the fuel consumption, thermal efficiency and pollutant emissions of various fuel/stove combination in field are rarely measured, although some were tested in laboratory. Since the difference between laboratory study and field measurement is clearly expected, it is strongly suggested to conduct more field tests on fuel consumption, burning efficiency, thermal efficiency and pollutant emissions in future study.

8. References

Anenberg, S.; Balakrishnan, K.; Jetter, J.; Masera, O.; Mehta, S.; Moss, J.; Ramanathan, V. Cleaner cooking solutions to achieve health, climate and economic cobenefits. Environmental Science & Technology 2013, 47, 3944-3952.

Anenberg, S.; Horowitz, L.; Tong, D.; West, J. An estimate of the global burden of anthropogenic ozone and fine particulate matter on premature human mortality using atmospheric modeling, Environ. Health Perspect. 2010, 118, 1189-1195.

Bonjour S., Adair-Rohani H., Wolf J., Bruce N., Mehta S., Prüss-Ustün A., Lahiff M., Rehfuess E., Mishra V., Smith K. Solid fuel use for household cooking: country and regional estimates for 1980-2010. Environmental Health Perspective 2013, 121, 637-642.

Brauer, M.; Amann, M.; Burnett, R. T.; Cohen, A.; Dentener, F.; Ezzati, M.; Henderson, S. B.; Krzyzanowski, M.; Martin, R.; Van Dingenen, R.; van Donkelaar, A.; Thurston, G. D. Exposure assessment for estimation of the global burden of disease attributable to outdoor air pollution, Environ. Sci. Technol. 2012, 46, 652-660.

Lei, Y.; Zhang, Q.; He, K.; Streets, D. Primary anthropogenic aerosol emission trends for China, 1990-2005. Atmospheric Chemistry and Physics 2011, 11, 931-954.

Lim, S.; Vos, T.; Flaxman, A.; Danaei, G.; Shibuya, K.; Adair-Rohani, H.; Amann, M.; Anderson, H.; Andrews, K.; Aryee, M.; Atkinson, C.; Bacchus, L.; Bahalim, A.; Balakrishnan, K.; Balmes, J.; Barker-Collo, S.; Baxter, A.; Bell, M.; Blore, J.; Blyth, F.; Bonner, C.; Borges, G.; Bourne, R.; Boussinesq, M.; Brauer, M.; Brooks, P.; Bruce, N.; Brunekreef, B.; Bryan-Hancock, C.; Bucello, C.; Buchbinder, R.; Bull, F.; Burnett, R.; Byers, T.; Calabria, B.; Carapetis, J.; Carnahan, E.; Chafe, Z.; Charlson, F.; Chen, H.; Chen, J.; Cheng, A.; Child, J.; Cohen, A.; Colson, K.; Cowie, B.; Darby, S.; Darling, S.; Davis, A.; Degenhardt, L.; Dentener, F.; Des Jarlais, D.; Devries, K.; Dherani, M.; Ding, E.; Dorsey, E.; Driscoll, T.; Edmond, K.; Ali, S.; Engell, R.; Erwin, P.; Fahimi, S.; Falder, G.; Farzadfar, F.; Ferrari, A.; Finucane, M.; Flaxman, S.; Fowkes, F.; Freedman, G.; Freeman, M.; Gakidou, E.; Ghosh, S.; Giovannucci, E.; Gmel, G.; Graham, K.; Grainger, R.; Grant, B.; Gunnell, D.; Gutierrez, H.; Hall, W.; Hoek, H.; Hogan, A.; Hosgood III, H.; Hoy, D.; Hu, H.; Hubbell, B.; Hutchings, S.; Ibeanusi, S.; Jacklyn, G.; Jasrasaria, R.; Jonas, J.; Kan, H.; Kanis, J.; Kassebaum, N.; Kawakami, N.; Khang, Y.; Khatibzadeh, S.; Khoo, J.; Kok, C.; Laden, F.; Lalloo, R.; Lan, Q.; Lathlean, T.;

Leasher, J.; Leigh, J.; Li, Y.; Lin, J.; Lipshultz, S.; London, S.; Lozano, R.; Lu, Y.; Mak, J.; Malekzadeh, R.; Mallinger, L.; Marcenes, W.; March, L.; Marks, R.; Martin, R.; McGale, P.; McGrath, J.; Mehta, S.; Mensah, G.; Merriman, T.; Micha, R.; Michaud, C.; Mishra, V.; Hanafiah, K.; Mokdad, A.; Morawska, K.; Mozaffarian, D.; Murphy, T.; Naghavi, M.; Neal, B.; Nelson, P.; Nolla, J.; Norman, R.; Olives, C.; Omer, S.; Orchard, J.; Osborne, R.; Ostro, B.; Page, A.; Pandey, K.; Parry, C.; Passmore, E.; Patra, J.; Pearce, N.; Pelizzari, P.; Petzold, M.; Phillips, M.; Pope, D.; Pope III, C.; Powles, J.; Rao, M.; Razavi, H.; Rehfuess, E.; Rehm, J.; Ritz, B.; Rivara, F.; Roberts, T.; Robinson, C.; Rodriguez-Portales, J.; Romieu, I.; Room, P.; Rosenfeld, L.; Roy, A.; Rushton, L.; Salomon, J.; Sampson, U.; Sanchez-Riera, L.; Sanman, E.; Sapkota, A.; Seedat, S.; Shi, P.; Shield, K.; Shivakoti, R.; Singh, G.; Sleet, D.; Smith, E.; Smith, K.; Stapelberg, N.; Steenland, K,; Stöckl, H.; Stovner, L.; Straif, K.; Straney, L.; Thurston, G.; Tran, J.; van Dingenen, R.; van Donkelaar, A.; Veerman, J.; Vijayakumar, L.; Weintraub, R.; Weissman, M.; White, R.; Whiteford, H.; Wiersma, S.; Wilkinson, J.; Williams, H.; Williams, W.; Wilson, N.; Woolf, A.; Yip, P.; Zielinski, J.; Lopez, A.; Murray C.; Ezzati, M. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. the Lancet 2013, 380, 2224-2260.

Puzzolo E., Stanistreet D., Pope D., Bruce N., Rehfuess E. 2011. What are the enabling or limiting factors influencing the large scale uptake by households of cleaner and more efficient household energy technologies, covering cleaner fuel and improved solid fuel cookstoves? A systematic review. Protocol. London: EPPI-Centre, social science research unit institute of education, University of London.

Shen, H.; Huang, Y.; Wang, R.; Zhu, D.; Li, W.; Shen, G.; Wang, B.; Zhang, Y.; Chen, Y.; Lu, Y.; Chen, H.; Li, T.; Sun, K.; Li, B.; Liu, W.; Liu, J.; Tao, S. Global atmospheric emissions of polycyclic aromatic hydrocarbons from 1960 to 2008 and future predictions. Environmental Science & Technology 2013. Doi:10.1021/es400857z.

Smith, K.; Gu, S., Huang, K.; Qiu, D. One hundred million improved cookstoves in China: How was it done? World development 1993, 21, 941-961.

Van Donkelaar, A.; Martin, R.; Brauer, M.; Kahn, R.; Levy, R.; Verduzco, C.; Villeneuve, P. Global estimates of ambient fine particulate matter concentrations from satellite-based aerosol optical depth: development and application, Environ.

Health Perspect. 2010, 118, 847-855.

Wang, R.; Tao, S.; Wang, W.; Liu, J.; Shen, H.; Shen, G.; Wang, B.; Liu, X.; Li, W.; Huang, Y.; Zhang, Y.; Lu, Y.; Chen, H.; Chen, Y.; Wang, C.; Zhu, D.; Wang, X.; Li, B.; Liu, W.; Ma, J. Black carbon emissions in China from 1949 to 2050. Environmental Science & Technology 2012, 46, 7595-7603.

Wei, W.; Zhang, W.; Hu, D.; Ou, L.; Tong, Y.; Shen, G.; Shen, H.; Wang, X. Emission of carbon monoxide and carbon dioxide from uncompressed biomass and pellet biomass fuels burned in typical household stoves in China. Atmospheric Environment 2012. 56, 136-142.

World Bank. State Environmental Protection Administration, P.R. China. 2007. Cost of pollution in China. Economic estimates of physical damages. www.worldbank.org/eapenvironment. Accessed May. 2013

Zhang, W.; Chen, X.; Liu, X.; Liu, G. Development of biomass stoves in China. Chemical Industry and Engineering Progress 2009, 28, 516-520. (In Chinese)

Zhao, Y.; Zhang, J.; Nielsen, C. The effects of recent control policies on trends in emissions of anthropogenic atmospheric pollutants and CO2 in China. Atmospheric Chemistry and Physics 2013, 13, 487-508.

Zhang, Y.; Dou, H.; Chang, B.; Wei, Z.; Qiu, W.; Liu, S.; Liu, W.; Tao, S. Emission of polycyclic aromatic hydrocarbons from indoor straw burning and emission inventory updating in China. Ann. N. Y. Acad. Sci. 2008, 1140, 218-227.

Zhang, J.; and Smith, K. Household air pollution from coal and biomass fuels in China: measurements, health impacts, and interventions, Environ. Health Perspect. 2007, 115, 848-855.

Air quality and health survey after deployment campaign

- **Qualitative study**

Liu YC, Guo YF, Liu F. Stoves improvement and indoor air pollution a abatement in rural area in China , Journal of Environment and Health 2011, 28, 240-241. ***Article ID.15***

Liu Y, Ye Y, Yang C, *et al*., Study on the satisfaction and the current situatyion of health stove use in Gulan county, Studies of trace elements and health 2013, 3, 36-38.***Article ID.16***

Guo X., Wang R, Wu JY, *et al*., Analysis of present situation of lowering fluoride stove's utilization in coal smoke fluorosis areas in Hunan province, Chinese Journal of Endemiology 2000, 19, 363-364. ***Article ID.23***

Cookstoves

Hao, F. The development of biomass briquetting fuels and cookstove industry in China. Agricultural Engineering Technology (New energy industry) 2009, 8, 5-7.

Hu, G., Liu, J., Liu, Y., *et al*., Investigation of the paths for improving stoves in rural area. Chinese journal of public health engineering, 2008, 2, 1-8.

Liu, S., Zhang, F., Liu, X., *et al*., Design and experiment of corn straw briquette stove, Transactions of the CSAE, 2009, 25, 101-103.

Wang, H., Wang, X., Wu, S., *et al*., Experimental study on the slagging characteristics and influential factors of the biomass briquette combustion stove. Journal of Henan agricultural university 2008, 42, 206-209.

Fan, X., Lu, Z., Li, D. *et al*., Performance of cooking stoves with biomass pellet fuel. Transactions of the CSAE 2010, 26, 280-284.

Zhang W, Chen X, Liu X, *et al*., Technology and development of Chinese biomass cookstove, Chemical industry and engineering progress 2009, 28,516-520.

- **Case/policy analysis**

Liu Y., Yang J., Wang H. The present development situation, problems and countermeasures of high efficiency and low emission in biomass stoves pilot in Shanxi province, Agricultural Engineering Technology (New Energy Industry) 2011, 11, 12-13. ***Article ID.58***

Guo J. Situation and development suggestions on economical firewood and coal stoves and Kangs , Agricultural Engineering Technology (New Energy Industry) 2011 , Z1, 63-64. ***Article ID.61***

- **Qualitative study**

Tang JH, Chen KJ, and Chen T.The promotion present situation and development Suggestions of save wood and coal stoves in Hubei province rural, Agricultural Engineering Technology (New Energy Industry) 2009, 8, 8-10. ***Article ID.21***

Household energy consumption

- **Case/policy analysis**

Tian YS. The status of rural energy in 2012 and future trend in China, China energy 2013, 35, 11-15. ***Article ID.01***

Gao GL. Rural residential energy consumption structure analysis in BaiYin district, Gansu Nongye 2009, 9, 34-36. ***Article ID.04***

Mo GS and Peng Y.Protection of the three gorges reservoir area ecological environment, Accelerate the development of rural energy, Agricultural Engineering Technology (New Energy Industry) 2010, 4, 29-30. ***Article ID.05***

Li W, Wang D, Li SC. Development policy of new energy industry in countryside based on low-carbon economy, Proceedings of the symposium of rural renewable energies and low-carbon technologies in China 2011, 4, 455-458. ***Article ID.10***

Zhou Z., Chen Q., Wang Q. *et al*., Development status, problems and countermeasures of biomass energy industry in Beijing suburb, Renewable Energy resources 2010, 28, 146-149. ***Article ID.34***

Han H, and Wu F. Rural renewable energy development present situation and the countermeasures in Baiji district, Agricultural Science and Technology 2008, 6, 1-3. ***Article ID.39***

Zhao C. The experience of Rural energy construction in Mingshan district, Modern Agriculture 2007, 12, 18-19. ***Article ID.40***

Wang J, and Zhao H. Analysis on the development of rural renewable energy in China, Resources & Industries 2007, 9, 78-79. ***Article ID.56***

Nie G. Qinghai province rural renewable energy development research, Ningxia Journal of Agriculture and Forest 2011, 52, 38-40. ***Article ID.57***

Hao L. Introduction to rural new energy construction in Jinzhong city, Shanxi province-the biomass furnace project as an example, Agricultural Engineering Technology (New Energy Industry) 2012, 6, 13-15. ***Article ID.59***

Wu D. The countermeasure research of rural new energy utilization promotion in our country, Rural economy 2012, 6, 94-96. ***Article ID.64***

Hao X. Rural energy problems and suggestions in our province, Henan science and technology 1983, 9, 8-14. ***Article ID.68***

Cai G, and Zhang L. Tibet rural energy consumption and environmental impact study, Resources development & market 2006, 22, 238-244. ***Article ID.70***

Li K, Liu C., Wei Y. China's energy poverty status quo analysis, Energy of China 2011, 33, 31-35. ***Article ID.85***

Xie D. China's rural biomass energy development opportunities, adjustment and development strategy, World agriculture 2010, 12, 28-30. ***Article ID.87***

- **Qualitative study**

Wang J, Ning X, Zhao M, *et al*., The Status and Analysis of Rural Household Energy Consumption in Henan Province, Henan science 2011, 29, 1384-1386 ***Article ID.18***

Wang R, Jiang A, Li N, *et al*., Research on Current Energy Sources Utilization in Desert Areas , Chinese Agricultural Science Bulletin 2007, 23, 396-400. ***Article ID.24***

Wu L, Zeng Q., Li W, *et al*., The research of Jinan rural life energy consumption structure , Shandong Agricultural Science 2007, 2, 93-96. ***Article ID.25***

Niu Y, Niu S., Zhang X. *et al*., Policy options on fuel use, energy conservation and emission reduction in household sector , China soft science2013, 5, 45-55 ***Article ID.27***

Wang X. Household energy consumption research in Jiangsu rural, Chinese Agricultural Science Bulletin 2012, 28, 196-200. ***Article ID.29***

Wang X. Survey and Analysis of Rural household Energy consumption at Yangzhong County in Jiangsu Province, Transactions of the CSAE 1994, 10, 102-107. ***Article ID.31***

Liu P., Chen K., Ding M. Forest biomass energy development-utilization situation and development countermeasures —A Case Study of Jianning county Fujian province , Economic research guide 2013, 15, 215-217. ***Article ID.36***

Wang X, and Hu X. Factors influencing rural household energy consumption, Transactions of the CSAE 2010, 26, 294-297. ***Article ID.42***

Lu H, and Lu L. An empirical analysis of the impact of famers' income level on the household energy consumption structure in the countryside, Finance and trade research 2006, 3, 28-34. ***Article ID.53***

Xi J, Zhao M, Ge Q.The evolution of household energy consumption model under the influence of rural tourism- Based on analysis of Liupan Mountain ecological tourist area of peasant household survey, Journal of natural resources 2011 , 26, 981-991. ***Article ID.72***

Liu J, Xie J, Zhang H, *et al*., Investigation and analyssi on energy consumption of rural township residences in Eastern Hunan , Journal of Hunan University of Technology 2013, 27, 26-29. ***Article ID.73***

Feng Y, and Wang X. Survey of rural household-energy consumption in Yangzhong county of Jiangsu Province, Acta agriculturae univerisitatis henanensis1996, 30, 405-408. ***Article ID.77***

Wang X., and Hu X. On factors influencing rural household energy consumption: exemplified by Lianshui county in Jiangsu Province , the 5th YRD forum on science and technology 2008, 45-47. ***Article ID.78***

Zhang N, Xu W, Cao P. A factor analysis for rural residential energy consumption: based on a rural household survey of 9 provinces , Chinese journal of

population science 2011 , 3, 73-82. ***Article ID.79***

- **Quantitative study**

Zhang X. and Niu SW. Empirical analysis of energy consumption demand in urban and rural households , China Population, resources and Environment2013, 23, 1-5***Article ID.07***

Zhou S, Cui Q, Wang C. Regional Disparities and Infuencing Factors of Rural Household Energy Consumption—A Case Study of Jiangsu and Jilin provinces, Journal of ecology and rural environment 2009, 25, 30-34. ***Article ID.28***

Wang D., Tang M., Ren Y., *et al*., Home energy carbon emission characteristics and influencing factors in Lijiang city, Acta Ecologica Sinica 2012, 32, 7716-7721. ***Article ID.35***

Zhang H., Mou J, Yin H. Family Life energy consumption demand empirical analysis - based on double extended linear expenditure system model in forest rural , Chinese rural Economy 2010, 7, 64-74. ***Article ID.37***

Chen S., Zheng X. Analysis in barriers in the supply and demand of renewable energy in rural area , Rural economy 2009, 12, 92-95 ***Article ID.43***

Yu B. Analysis on peasant household energy factor and policy implication on the popularization of new energy-in Nanjing city, Jiangsu province, for example, Nanjing Agricultural Univeristy 2007. ***Article ID.51***

Yang J, Gao M, Zhang, P, *et al*., Empirical analysis of influencing factors of technology choice about agriculture and rural energy-saving and emission reduction, Chinese Agricultural Science Bulletin 2009, 25, 406-412. ***Article ID.54***

Lou B, Xu J, Lv K. Sichuan farmers life energy consumption situation analysis , Journal of Anhui Agricultural Science 2008, 36, 1681-1687. ***Article ID.62***

Wu Y, Shen Y, Yan F. Study on rural distributed and renewable energy selection by multivariable regression analysis-based on the survey of Gaojiazhuang of Hebei province, Chinese Agricultural Science Bulletin 2012, 28, 248-253. ***Article ID.63***

Fei Z.and Yu ZG. An analysis on present situation and consumption desire of clean energy in China's rural area based on a survey of famer-households in six cities of five provinces, Power system and clean energy 2011 , 27, 60-64. ***Article ID.67***

Qiao S. Research on the alternative energy in western poor rural areas- based on the questionnaires in northwest Yunnan , Journal of Agrotechnical economics 2010, 4, 78-85. ***Article ID.69***

Liang Y, Fan J, Sun W, *et al*., The influence factors of southwest mountainous rural life energy consumption structure analysis-the Shaotong city, Yunnan province as an example, Acta Ecologica Sinica 2012, 67, 221-229. ***Article ID.71***

Wu W, Liu Q, Xie T, *et al*., The energy consumption demands for farmers surrounding the conservation of nature- based on the empirical analysis of Zhejiang and Shaanxi province, Journal of Agrotechnical economics 2012, 5, 43-49. ***Article ID.90***

Biogas

- **Case/policy analysis**

Jiang SY, Sun SB, and Chen Q. The investigation of the development of rural biogas construction in Anding district, Develping2008, 5, 38 ***Article ID.02***

Kang HX. The rural biogas construction present situation and development trend of trends in BaYanZhuoEr city , Inner Mongolia Agricultural Science and Technology 2009, 2, 104-405. ***Article ID.03***

Wang YM, Lin RH, and Bai ZM. The economic evaluation of "The trinity" biogas ecological model in the north, Renewable energy 2005, 2, 39-42. ***Article ID.06***

Zhou JQ, Sun W, and Li Y. Feasibility Study for the Industrialization of rural Energy in Henan under the Urbanization Sight , Science and Technology Innovation Herald 2013, 5 , 148-150. ***Article ID.08***

Zhou G, and Shu CQ. The discussion on Enshi rural biogas energy promotion strategy , Journal of Enshi Technical College 2007, 19, 59-62. ***Article ID.12***

Jiao R. Development of biogas clean energy, Change the rural residential environment, Agricultural Engineering Technology (New Energy Industry) 2012, 11, 33-34. ***Article ID.13***

Ning S. Biogas development is the inevitable choice of the new rural construction , Agricultural Engineering Technology (New Energy Industry) 2009, 8, 34-35. ***Article ID.14***

Yun F, Gao F, Wang K. The cause and countermeasures of the biogas slow development in Hebei province rural, China biogas 1992, 10, 47-48. ***Article ID.17***

Wang Y, Xia P, Fei Z. Biogas construction theory and the practice question in Jixi, heilongjiang province , China collective economy 2012, 12, 181-182. ***Article ID.19***

Xu H. The construction present situation and development prospect thinking of rural biogas in Hohhot City, Modern Agriculture 2007, 2, 1-2. ***Article ID.20***

Li W, Xue H, Wang J, *et al*., Investigation on Energy Mode of Rucheng County and Biogas Industry Developing Countermeasures in South China , China biogas 2007,25, 32-36. ***Article ID.22***

Gao Z. The thought and countermeasures of accelerate rural biogas development , Agricultural Engineering Technology (New Energy Industry) 2011 , 8, 19-20. ***Article ID.26***

Xu Y., Chen J., Chen M. Economic Benefit Evaluation for Rural Household Biogas in the Central Area of Jiangsu, Journal of Anhui Agricultural Science 2013, 41, 391-392. ***Article ID.30***

Chen Y, Yang G, Feng Y, *et al*.,Analysis of resources of biogas in rural area, Journal of Northwest A&F University 2009, 37, 200-207. ***Article ID.41***

Nie W, and Yang H. Rural new energy development and utilization should be more simultaneously, Yunan agriculture 2011 , 3, 46-47. ***Article ID.45***

Zhao H. Obstacles and countermeasures in the development of rural biogas in industrialization , China biogas 2005, 23, 121-124. ***Article ID.48***

Yang Y. Introduction to the construction of rural energy development machine utilization of biogas, China science and Technology review 2012, 4, 54. ***Article ID.55***

Li C. Ponders on promoting the development of our rural biogas , Agricultural Engineering Technology (New Energy Industry) 2012 , 10, 6-7. ***Article ID.66***

Chen J, Yang L, Wang X. Difficulties and utilization of biogas energy In the new rural construction - a case study of biogas energy utilization in Gongcheng city Guangxi province , Innovation of rural construction and environmental technology 2006, 85-88. ***Article ID.74***

Ma J. The development of rural biogas construction ideas and countermeasures under the new situation , Agricultural Engineering Technology (New Energy Industry) 2010, 7, 4-5. ***Article ID.75***

Geng L. Biogas change is not only the farmhouse kitchen- rural biogas industrialization sidelights in Yongdeng county, Develping 2006, 8, 42-43. ***Article ID.82***

Liu Y, and Jia W. Biogas- the effective way of rural new energy development , Jilin Nongye 2011 , 19, 51. ***Article ID.83***

Shi J, Yang G, Guo Y, *et al*.,China's household biogas technology transfer restriction factor analysis and countermeasures , Chinese Agricultural Science Bulletin

2005, 6, 433-436 ***Article ID.84***

- **Qualitative study**

Luo HL, Liu YL, and Li RR. The present situation and development countermeasures of rural renewable energy, A Case of Jinghong ounty in Yunnan province , Sustainable development 2008, 2, 80-82. ***Article ID.09***

Hu C, Hu B, Li H, *et al.*, The investigation and thinking of household Methane gas in the construction of new rural energy problem in Suining city, Journal of Sichuan Vocatrional and Technical College 2008, 18, 29-30. ***Article ID.11***

Chang X. Linfen city Agricultural resources environmental and the investigation and discussion of the rural renewable energy, Agricultural Engineering Technology (New Energy Industry) 2009, 9, 24-27. ***Article ID.38***

Zhou L, and Huang J. The rural biogas construction problems and countermeasures-Longhui county in Hunan province as an example, Anhui agriculture 2012, 6, 272-274. ***Article ID.46***

Lei P, Miao T, Zhang Y, *et al.*, Rural biogas socialized service supply - demand survey –the tube station of the earthquake reconstruction area in Majin town of Shifang city as an example, Renewable Energy resources 2011 , 29, 153-156. ***Article ID.47***

Lu H, and Liu H. Energy-consuming structure of rural family with and without biogas disgester and developing tendency , China biogas 2006 , 24, 19-26. ***Article ID.80***

- **Quantitative study**

Yang Z. The rural renewable energy supply and demand analysis of the system obstacles , Transactions of the CSAE 2011 , 27, 268-273. ***Article ID.44***

Sheng Y., Studies on the factors of rural hosueholds' adoption of biogas: based on the huade county and Zhalaite district survey , Inner Mongolia University 2010.***Article ID.49***

Cui Q, Wang C. Study on influencing factors of choosing renewable energy biogas-a case study on rural household biogas in Jiangsu Province, Chinese Agricultural Science Bulletin 2009, 25, 273-276. ***Article ID.50***

Zhu L and Zhao Y. Analysis of methane emission reduction effect and factors on farmers' adoption behavior , China Population, resources and Environment2012, 22, 35-39. ***Article ID.81***

Wang H, Yang Z, and Geng YQ. Analysis on the influence factors of rural household biogas production in China , Renewable energy resources 2007, 25, 106-109. ***Article ID.86***

Wang H, and Xin X.China's rural biogas consumption and its influencing factors, China rural economy 2007, 11, 59-65. ***Article ID.89***

Electricity

- **Quantitative study**

Zhang N, Xu W. Farmers living power consumption analysis - based on energy from the choice behavior, Chinese rural economy 2011 , 7, 72-84. ***Article ID.52***

Straw gasification

- **Case/policy analysis**

Wang H. Plenty of opportunities in the development of straw gasification, Construction Science and Technology 2005, 12, 32-33. ***Article ID.33***

Yin L. and Yin C. Promotion of straw gasification in a timely manner should be thinking about , Management and research on scientific & technological achievements 2012, 9, 58-60. ***Article ID.65***

Li Y, Song Y, Nan F. Discussion on construction and operator mode on new type biomass gasification station, Renewable resources and recycling economy2008, 1, 27-30. ***Article ID.76***

Compressed biofules

- **Case/policy analysis**

Yang J, Wen W, Feng C. The Suggestion on policy of the rural straw densification briquetting fuel shaping technology in china, China resources comprehensive utilization 2006, 24, 30-33. ***Article ID.32***

- **Qualitative study**

Liu J. the mechanism design and policy research of straw briquette fuel promotion in rural areas, Nanjing Agricultural University 2007. ***Article ID.60***

Ma L, Zhang D, Liu Z, *et al.*, Analysis of forming an obstacle to the development of solid biomass, Forestry economics 2010, 1, 107-110. ***Article ID.88***

Appendix

	Author	Year	Title	Research method	Sample size	Data analysis	Main content and conclusions
1	Tian YS.	2013	The status of rural energy in 2012 and future trend in China				Analysis of the current status of energy development in rural China-planning and law, investment and subsidy, technical standard, market development and CDM program
2	Jiang SY, Sun SB, Chen Q.	2008	The investigation of the development of rural biogas construction in Anding district				Abundant crop straw fuel, the development of livestock feeding, several biogas utilization modes, and appropriate natural conditions are good for the biogas development Strengthen the leadership, increase the investment, and technical guide, form management and service team
3	Kang HX.	2009	The rural biogas construction present situation and development trend of trends in BaYanZhuoEr				Deployed in the program under the combined support from the government and self-financing Do a good planning, promote

			city				deployment in programs, start in several pilots and then expand
4	Gao GL.	2009	Rural residential energy consumption structure analysis in BaiYin district	Interview and questionnaires			Positively correlated with location and economic conditions. The consumptions of commercial cleaner fuels are higher in areas with convenient transport and good economic conditions
5	Mo GS and Peng Y.	2010	Protection of the three gorges reservoir area ecological environment, Accelerate the development of rural energy				Programs of public facilities grants, national debts, loan from world bank Give publicity through feature film, TV and radio programs and demonstration of fuel adoption Enhance the guideline of government to promote biogas development Increase the financial investment and subsidy to inspire the adoption enthusiasm Scientific and good planning of county and biogas development Form a professional service team

6	Wang YM, Lin RH, and Bai ZM.	2005	The economic evaluation of "The trinity" biogas ecological model in the north				Significant factors include the production rate of biogas, price of coal, the livestock feeding, the price in pool building (material and labor)
7	Zhang X. and Niu SW.	2013	Empirical analysis of energy consumption demand in urban and rural households	Questionnaires and interview	820	Expanded Linear Expenditure System (ELES)	When house income increased 1 RMB, there would be 0.044 used for residential energy in urban and 0.065 in rural area, respectively The coefficient of elasticity in income less than 1, indicating a small influence of house income on residential energy consumption
8	Zhou JQ, Sun W, and Li Y.	2013	Feasibility Study for the Industrialization of rural Energy in Henan under the Urbanization Sight				Main barriers: simple pool building technology, unsteady gas production, low self-financing, the lack of professional technical team and lack of pool maintenance
9	Luo HL, Liu YL, and Li RR.	2008	The present situation and development countermeasures of rural renewable energy, A Case of Jinghong ounty in Yunnan province	Field survey and questionnaires			Solar energy: simple and single utilization, high failure affecting the adoption enthusiasm Biogas: lack of knowledge and awareness, without technical support

							and good management, lack of financial support Suggestions: publicity, encourage to develop new energies like wind energy and solar energy, innovation in technology development, the production-study-research combination
10	Li W, Wang D, Li SC.	2011	Development policy of new energy industry in countryside based on low-carbon economy				Deficiency in energy policy: 1 lack of detailed rules and corresponding policy; 2) incentive limited; 3) innovation in research and quality assurance; 4) guide to adopt new fuels
11	Hu C, Hu B, Li H, *et al*.,	2008	The investigation and thinking of household Methane gas in the construction of new rural energy problem in Suining city	Questionnaires and in-depth interview	250		Suggestion: 1) combine the development of biogas and livestock feeding; 2) financial support from different aspects; 3) more support in research; 4) improve the comprehensive utilization; 5) good management system
12	Zhou G, and Shu CQ.	2007	The discuss on Enshi rural biogas energy promotion strategy				Advantage: suitable climate condition, technical support, social roots, the strategy of ecological county, the

							strategy of sustainable development Innovations in perception, planning, technology, financial investment, policy and service
13	Jiao R.	2012	Development of biogas clean energy, Change the rural residential environment				Problems: less sustainable use and few comprehensive utilization Suggestion: publicity, demonstration, training, ensure the quality of pool, develop the comprehensive utilization and improve follow-up service
14	Ning S.	2009	Biogas development is the inevitable choice of the new rural construction				The leader paid high attention to the biogas development, give the publicity, give financial support, enhance the training, do a good planning and several good demonstration pilots, follow-up management and service
15	Liu YC, Guo YF, Liu F.	2011	Stoves improvement and indoor air pollution abatement in rural area in China	Field measurement		SPSS, wilcoxon test	Indoor CO and SO2 decreased by 38 and 61%, respectively Personal exposure SO2 decreased 30%

							Coal consumption decreased from 0.83-0.88 to 0.50-0.53 kg/h and thermal efficiency improved from 8.2 to 25%
16	Liu Y, Ye Y, Yang C, *et al*.,	2013	Study on the satisfaction and the current situation of health stove use in Gulan county	Face to face interview	780	Epitats and SPSS analysis	42% households did not participate into the adoption program because no subsidy from the government, 7% because poor economic conditions, 30% gave up the use after the adoption, 16% used both improved and old stoves in mixture and 14% only use old stoves 58% of stoves were in destroy, only 25% cleaned regularly, 44% clean the stove when backed and 26% did not clean The main reason for abandon is no new accessories (21%), followed by inconvenient use (21%), can not meet the need of cooking (18%) and waste of coal (13%)

17	Yun F, Gao F, Wang K.	1992	The cause and countermeasures of the biogas slow development in Hebei province rural				Lower gas production rate, difficulty in tap, and only available in 6 months prevent the adoption Suggestion: modern new technology, pilot demonstration, technical service team and self-financing by residents in pool building
18	Wang J, Ning X, Zhao M, *et al*.,	2011	The Status and Analysis of Rural Household Energy Consumption in Henan Province	Interview and panel discussion	540		Main barriers: awareness of the importance and high prices of coal-saving stove Suggestion: policy, research and publicity
19	Wang Y, Xia P, Fei Z.	2012	Biogas construction theory and the practice question in Jixi, heilongjiang province				Lack of awareness and perception; Simple utilization; insufficient investment; simple and crude pool building, high abandon percent, lack of suitable systems Suggestion: publicity, training; innovation; financial support

20	Xu H.	2007	The construction present situation and development prospect thinking of rural biogas in Hohhot City				Problems: knowledge and awareness; less pilots; lacking of financial support in research and deployment; utilization of biogas residue; no professional technical team
21	Tang JH, Chen KJ, and Chen T.	2009	The promotion present situation and development Suggestions of save wood and coal stoves in Hubei province rural	Questionnaires			Biogas use is affected by natural conditions, varies in seasonality; cannot meet the need during the festival Problems in deployment of fuel-saving stoves: technology, research, standard, regulations and market development
22	Li W, Xue H, Wang J, *et al.*,	2007	Investigation on Energy Mode of Rucheng County and Biogas Industry Developing Countermeasures in South China				Problems in biogas use: raw material supply and livestock feeding; difficulty in tap, quality of biogas pool Suggestion: technology innovation in pool building, improve the gas production rate, for a good

							management and technical service team, publicity
23	Guo X., Wang R, Wu JY, *et al*.,	2000	Analysis of present situation of lowering fluoride stove's utilization in coal smoke fluorosis areas in Hunan province	Indoor survey			Only 50% stoves are in good condition after a long period use, and in some counties, almost all were in destroy High destroy rate in accessories
24	Wang R, Jiang A, Li N, *et al*.,	2007	Research on Current Energy Sources Utilization in Desert Areas	Questionnaires, interview and observation			Influencing factors: location, habits, economic conditions and stove technology
25	Wu L, Zeng Q., Li W, *et al*.,	2007	The research of Jinan rural life energy consumption structure	Semi-structural interview	250	Participatory rural assessment (PRA)	Energy consumption positively correlated with income per capita Many peole know about biogas, but only 9.1% adopted under the support of government Only 9 and 4% use energy-saving coal and wood stoves, though 64 and 82% heared about the improved stoves-because the deployment was during the 1980s-1990s, after that many

							residents did not know about the improved stoves Suggestion: publicity, center heating system; innovation in technology; market development
26	Gao Z.	2011	The thought and countermeasures of accelerate rural biogas development				Problems: publicity, poor pool quality, lack of raw material; no professional team; follow-up service; investment; comprehensive utilization Countermeasures: publicity, safe operate, technology support, demonstration and pilot; investment and promote comprehensive utilization
27	Niu Y, Niu S., Zhang X. *et al.*,	2013	Policy options on fuel use, energy conservation and emission reduction in household sector	Questionnaires	820		With the development of economic conditions, the household energy tend to switch to cleaner commercial fuels The increase of income will result in demand of high quality fuel
28	Zhou S, Cui Q, Wang C.	2009	Regional Disparities and Infuencing Factors of Rural Household Energy	Questionnaires and interview	500	Multi-linear regression model	Per capita consumption: the consumption of commercial energy increased with the increase of house

			Consumption—A Case Study of Jiangsu and Jilin provinces				income, housing area, family size Biogas adoption: increased with the increase of income before 9217 RMB, and decreased after that, switching to LPG; the chance increased 18% with one more livestock; 10.9% with 1 year increased education External factors: tax and subsidy, increase the use of biogas 49%
29	Wang X.	2012	Household energy consumption research in Jiangsu rural	Questionnaires	2835	SPSS statistical analysis	With the increase of house income, energy consumption per capita decreased
30	Xu Y., Chen J., Chen M.	2013	Economic Benefit Evaluation for Rural Household Biogas in the Central Area of Jiangsu				The proportion of commercial energy increase with the development of economy, and biogas may became less important Lack of raw material from livestock feeding, people going out for work and difficulty in tap and maintenance are barriers in biogas development

							Countermeasures: comprehensive utilization; tax and policy; combination with pollution control
31	Wang X.	1994	Survey and Analysis of Rural household Energy consumption at Yangzhong County in Jiangsu Province	Questionnaires	384	SPSS	Energy consumption increased with income increase The increase of electricity is faster than the other fuels Consumption per capita decreased with the increase of family size Prefer to use LPG because of convenience, comfort and clean Coal is also convenient but required additional cost
32	Yang J, Wen W, Feng C.	2006	The Suggestion on policy of the rural straw densification briquetting fuel shaping technology in china				Barriers in economy-high cost, can not afford Barriers in operation and management-lacking of enough labor and high quality service team Barriers in policy-incentive Barriers in information-lack of publicity and demonstration

33	Wang H.	2005	Plenty of opportunities in the development of straw gasification				Economical condition, centered distribution of households, good planning, To consider market development
34	Zhou Z., Chen Q., Wang Q. *et al.*,	2010	Development status, problems and countermeasures of biomass energy industry in Beijing suburb				Problems: low density and complicated composition that difficult to utilize; lacking of technology and innovation; secondary pollution; market development; follow-up service system; cooperation
35	Wang D., Tang M., Ren Y., *et al.*,	2012	Home energy carbon emission characteristics and influencing factors in Lijiang city	Questionnaires	300	SPSS regression analysis	Large family size, more livestock, higher education are beneficial
36	Liu P., Chen K., Ding M.	2013	Forest biomass energy development-utilization situation and development countermeasures —A Case Study of Jianning	Questionnaires and interview	126		Active attitude but less awareness Suggestion: inspire the enthusiasm, give the publicity and subsidies

			county Fujian province				
37	Zhang H., Mou J, Yin H.	2010	Family Life energy consumption demand empirical analysis - based on double extended linear expenditure system model in forest rural	questionnaires	3180	Expand linear Expenditure System	marginal propensity to consume with the increase of income: LPG, electricity, coal, straw, biogas and wood.
38	Chang X.	2009	Linfen city Agricultural resources environmental and the investigation and discussion of the rural renewable energy	Questionnaires, interview and panel discussion	250 questionnaires; interview in 300 households, and discussed 30 times		Biogas: 60% not in use because of no livestock feeding (60%), poor pool quality (10%), no follow-up service (15%) and migration (10%) 70% are willing to adopt biogas because higher price of coal (80%), convenient use (10%) and utilization in agricultural production (5%) Affordable cost in pool building: lower than 500 RMB (50%), 500-1000 RMB (30%) and 1000-2000 RMB (15%) Suggestion: set up an agency to emphasis the deployment; policy,

							training and follow-up service
39	Han H, and Wu F.	2008	Rural renewable energy development present situation and the countermeasures in Baiji district				Lacking of awareness, simple and single utilization; lower technology level; poor service, no market development
40	Zhao C.	2007	The experience of Rural energy construction in Mingshan district				Comprehensive utilization; pilot, publicity, policy
41	Chen Y, Yang G, Feng Y, *et al*.,	2009	Analysis of resources of biogas in rural area				Favorable for biogas development: 7-12 months with the ground temperature higher than 10 ^{o}C; 6 months with high ground temperature with abundant solar energy resource Energy consumption per capita decreases with the increase of population, non-linear
42	Wang X, and Hu X.	2010	Factors influencing rural household energy consumption	questionnaires	356	SPSS	Insignificant with the number of pig The consumption of electricity increased with the increase of income
43	Chen S.,	2009	Analysis in barriers in the		117	Binary choice	Centered distribution is beneficial for

	Zheng X.		supply and demand of renewable energy in rural area			mode	the development of renewable energies; The influence of population is insignificant; The influence of governmental service efficiency is significant; House income significantly affects the adoption; More public financial investment, more residents participating into adoption group
44	Yang Z.	2011	The rural renewable energy supply and demand analysis of the system obstacles			STIRPAT (Stochastic impacts by regression on population, affluence and technology) and regression model	Income per capita affects the use of electricity significantly Biogas development can be promoted better among low income countries
45	Nie W, and Yang H.	2011	Rural new energy development and utilization should be more simultaneously				Difficulty in biogas development: building engineering, treatment of waste, lobar, difference in knowledge and income, lack of money, publicity and awareness

46	Zhou L, and Huang J.	2012	The rural biogas construction problems and countermeasures-Longhui county in Hunan province as an example	Questionnaires, Interview	120		Biogas contributed 65% of residential energy, for cooking, bathing, and lighting Problems: difficulty in tap, unsteady gas production, the comprehensive utilization efficiency is low, lack of knowledge and awareness; investment; follow-up service
47	Lei P, Miao T, Zhang Y, *et al.*,	2011	Rural biogas socialized service supply - demand survey –the tube station of the earthquake reconstruction area in Majin town of Shifang city as an example	questionnaires	82		Only 39% households used biogas for cooking 2-3 times/day In addition to the natural condition, the influence of social factors is more obvious Labor going out for work-maintenance; awareness of comprehensive utilization; problems in biogas stove
48	Zhao H.	2005	Obstacles and countermeasures in the				Simple construction of biogas pool and low quality; lack of commercial

			development of rural biogas in industrialization				accessories
49	Sheng Y.,	2010	Studies on the factors of rural hosueholds' adoption of biogas: based on the huade county and Zhalaite district survey		60	Binary-choice model, Logit regression analysis	External factor: rural culture, organization to deploy the new fuel; management system Internal factor: knowledge and attitude of the new technology Suggestion: publicity, for the organization and technical service team, improve education level
50	Cui Q, Wang C.	2009	Study on influencing factors of choosing renewable energy biogas-a case study on rural household biogas in Jiangsu Province	Questionnaires and interview	250	Probit analysis	House income is negatively correlated with biogas use, the chance decreases 19% with per 1000 RMB increase; the chance increases 10% with 1 more year education; the chance decreases 3.8% with 1% population migrating out for work; external factors: tax and subsidy, and technical support
51	Yu B.	2007	Analysis on peasant		288	Regression	House income-promote the adoption

			household energy factor and policy implication on the popularization of new energy-in Nanjing city, Jiangsu province, for example			analysis	of commercial energy and reduce biofuels use after increase; Increased number of stove increased the consumption of corresponding fuels, like coal and LOG, but not for electricity, which is due to different usage; Size and labor positively correlated with energy consumption, and education level negatively correlated with biofuels consumption amount; Barriers in biogas utilization: not willing to feed pig, work outside without enough labor to maintenance the pool
52	Zhang N, Xu W.	2011	Farmers living power consumption analysis - based on energy from the choice behavior	questionnaires	360	Treatment-effects model	Electricity use increase with increased income; positively correlated with total residence time; The old are used to traditional solid fuels while the young children increased electricity consumption; The influences of education, household structure and layout are

							insignificant;
53	Lu H, and Lu L.	2006	An empirical analysis of the impact of famers' income level on the household energy consumption structure in the countryside	Questionnaires and panel discussion	726		Economic index: biogas, LPG, electricity Convenience: biomass<coal<LPG Comfort: LPG>electricity>biogas Cleanness: LPG, electricity, biogas> biomass High income residents prefer to use comfort, convenient and clean fuels, while low income ones consider the cost of fuel
54	Yang J, Gao M, Zhang, P, *et al*.,	2009	Empirical analysis of influencing factors of technology choice about agriculture and rural energy-saving and emission reduction	Questionnaire	60	Logit analysis	Biogas: positively correlated with the pollution control possibility; under the support of government Solar energy: positively correlated with education level and can promote with subsidies
55	Yang Y.	2012	Introduction to the construction of rural energy development machine utilization of				Problems: low participate enthusiasm, follow-up service, and low comprehensive utilization efficiency

			biogas				
56	Wang J, and Zhao H.	2007	Analysis on the development of rural renewable energy in China				Low utilization efficiency, cause pollution, simple and single utilization; needs to conduct scientific research
57	Nie G.	2011	Qinghai province rural renewable energy development research				Simple utilization, low technology, follow-up service, publicity and awareness
58	Liu Y., Yang J., Wang H.	2011	Status, problems and countermeasures in the pilot of high efficient low emission stove in Shanxi province				Problems: development in briquetting technologies; supply of accessories, and investment and subsidies
59	Hao L.	2012	Introduction to rural new energy construction in Jinzhong city, Shanxi province-the biomass furnace project as an example				Publicity, demonstration and management result in good deployment results Problems: low economic support to residents, lack of professional service team and technology innovation
60	Liu J.	2007	the mechanism design and policy research of straw briquette fuel	Questionnaire and face-to-face interview			50% think the use can save time and fuel, benefit for health, thus willing to adopt

			promotion in rural areas				The price and supply are main influencing factors; influence of education level is not significant; the effects of demonstration is obvious; with the increase of income, the willing to adopt will increase
61	Guo J.	2011	Situation and development suggestions on economical firewood and coal stoves and Kangs				Most stoves are built by residents themselves without technical guideline, the market is not developed
62	Lou B, Xu J, Lv K.	2008	Sichuan farmers life energy consumption situation analysis	Questionnaire	120	STATA analysis	Influencing factors include the income, price of fuel, accessibility, size of family, livestock feeding and tax and subsides
63	Wu Y, Shen Y, Yan F.	2012	Study on rural distributed and renewable energy selection by multivariable regression analysis-based on the survey of Gaojiazhuang of Hebei	Questionnaire and interview	152	Logistic analysis	The relationship between adoption of biogas and income is a quadratic curve The use chance increased with the increase of education level

			province				
64	Wu D.	2012	The countermeasure research of rural new energy utilization promotion in our country				Problems: awareness, technical support, detailed rules and regulations
65	Yin L. and Yin C.	2012	Promotion of straw gasification in a timely manner should be thinking about				Need large investments, in the pilot period, to establish good management system on gasification station
66	Li C.	2012	Ponders on promoting the development of our rural biogas				Lack of knowledge and perception, no enough raw material causing the abandon of biogas pool Problems in follow-up service, management, training and comprehensive utilization of both gas and residues
67	Fei Z.and Yu ZG.	2011	An analysis on present situation and consumption desire of	Questionnaire and interview	350	logistic analysis	Significant factors: gender, how to know about the clean fuel, subsidy, education, and income

			clean energy in China's rural area based on a survey of famer-households in six cities of five provinces				
68	Hao X.	1983	Rural energy problems and suggestions in our province				No standard and measurement in pool building and test, heavily depending on personal experience Low pool quality leads to low gas production ability
69	Qiao S.	2010	Research on the alternative energy in western poor rural areas-based on the questionnaires in northwest Yunnan	Questionnaire	288	OLS and Logit analysis	Firewood consumption: location, house income (very small influence); distance to find wood (no influence-inflexibility)
70	Cai G, and Zhang L.	2006	Tibet rural energy consumption and environmental impact study				Increase income and reduce loan will promote the switch to cleaner fuels
71	Liang Y, Fan J, Sun W, *et al*.,	2012	The influence factors of southwest mountainous rural life energy	Questionnaire	1000	Tobit model	Firewood consumption is positively with wood abundance, the distance to purchase other fuel, and house income,

			consumption structure analysis-the Shaotong city, Yunnan province as an example				and negatively correlated with family size, education level, and in households with labor going out for work, the use of biomass fuel is low; Coal: negatively correlated with distance to purchase coal and the price of coal, negatively correlated with electricity since areas using electricity are usually developed regions
72	Xi J, Zhao M, Ge Q.	2011	The evolution of household energy consumption model under the influence of rural tourism- Based on analysis of Liupan Mountain ecological tourist area of peasant household survey	Questionnaire	170		The increase of house income is main reason, and awareness is important
73	Liu J, Xie J, Zhang H, *et al.*,	2013	Investigation and analyssi on energy consumption of rural township residences in Eastern Hunan	Questionnaire	120		LPG becomes popular with the increase of living standard, but in many poor areas, the use of firewood is common and contributed largely to total energy consumption;

							Household adobe structure-72% using firewood; brick-wood structure-57 and 21% using briquette and LPG; concrete structure-48 and 32% using briquette and LPG
74	Chen J, Yang L, Wang X.	2006	Difficulties and utilization of biogas energy In the new rural construction - a case study of biogas energy utilization in Gongcheng city Guangxi province				Biogas use affects by external factors like price of feed and cost in livestock feeding Problems: follow-up service, professional teams and purchase of accessories
75	Ma J.	2010	The development of rural biogas construction ideas and countermeasures under the new situation				Experience: publicity, emphasis, demonstration, investment, technical training Problems: low adoption, follow-up service; market development of stove and accessories; low technology, low comprehensive utilization efficiency and lack of raw material
76	Li Y, Song Y, Nan F.	2008	Discussion on construction and operatire				Problems: low quality of gas and gas station, safety and financial problem

			mode on new type biomass gasification station				
77	Feng Y, and Wang X.	1996	Surbey of rural household-energy consumption in Yangzhong county of Jiangsu Province	Questionnaire	384		Electricity is popular, especially with increased income; Biogas became less popular since many residents are switching to use LPG Problems in biogas development: investment, unsteady gas production, problems in tap, no raw materials
78	Wang X., and Hu X.	2008	On factos influencing rural household energy consumption: examplified by Lianshui county in Jiangsu Province	Questionnaire	300		Energy consumption per capita negatively correlated with population The consumption of electricity is significantly correlated with income
79	Zhang N, Xu W, Cao P.	2011	A factor analysis for rural residential energy consumption: based on a rural household survey of 9 provinces	interview			The influence of income is most significant; Higher education levels, easier to adopt new things. The chance to use high quality clean fuels increased 0.66% with 1 a education; The chance in concrete structure

							household is 5.67% higher than the others; The influence of location: temperature and heating days.
80	Lu H, and Liu H.	2006	Energy-consuming structure of rural family with and without biogas disgester and developing tendency	Questionnaire and professional discussion	726		Income per capita less than 4000: biogas if available or traditional fuels; those higher than 4000 prefer to use LPG
81	Zhu L and Zhao Y.	2012	Analysis of methane emission reduction effect and factors on farmers' adoption behavior	Questionnaire	160	Logit analysis	The female prefer to adopt clean new fuels; The old are used to traditional fuels; Positive factors: livestock feeding, organization; awareness of environmental protection; Negative impacts of national debt, which means should support in forms of subsides and special funds
82	Geng L.	2006	Biogas change is not only the farmhouse kitchen-rural biogas industrialization sidelights in Yongdeng				Problems: lack of awareness and initiative, not suitable site to build the pool causing low gas production rate; low comprehensive utilization efficiency and insufficient support in

			county				management and technical service
83	Liu Y, and Jia W.	2011	Biogas- the effective way of rural new energy development				Large labors required in pool building and maintenance, more labors go out for work lead to the abandon of biogas; Lack of financial support and publicity
84	Shi J, Yang G, Guo Y, *et al*.,	2005	China's household biogas technology transfer restriction factor analysis and countermeasures				Problems: incomplete development of market. In most cases, the adoption is required by the government with exact number Suggestion: technology development, management, awareness, labor resource, and management
85	Li K, Liu C., Wei Y.	2011	China's energy poverty status quo analysis				It is not the prior choice to change household energy for low income families The increase of income may not promote the switch to cleaner high-quality fuels

86	Wang H, Yang Z, and Geng YQ.	2007	Analysis on the influence factors of rural household biogas production in China	Statistical data from yearbook		Regression analysis	Livestock feeding-positive; temperature-positive; House income-negative; Demonstration and incentive-positive; Education level-insignificant;
87	Xie D.	2010	China's rural biomass energy development opportunities, adjustment and development strategy				Problems: raw material supply, technology, standards, policy and subsides, and relatively high cost that residents can not afford it
88	Ma L, Zhang D, Liu Z, *et al*.,	2010	Analysis of forming an obstacle to the development of solid biomass	Questionnaire and interview	140		Problems: low income to grow food and thus lack of material; no awareness and low initiative; mainly and used to use coal; lack of awareness of environmental protection; lack of knowledge of new fuel type-about 64% did not hear about the fuel Barriers: supply of raw material, fuel consumption habits, knowledge and policy
89	Wang H,	2007	China's rural biogas	Statistical data		Regression	The influence of income is non-linear.

	and Xin X.		consumption and its influencing factors	from yearbook		analysis	Education level-negative impact since it is not a new technology; The price of commercial fuels-negative Number of livestock-positive; Ground temperature-negative, this is because in their study the temperature is from the statistical yearbook which can not represent the real
90	Wu W, Liu Q, Xie T, *et al.*,	2012	The energy consumption demands for farmers surrounding the conservation of nature-based on the empirical analysis of Zhejiang and Shaanxi province	Questionnaire	192	Regression analysis	Income-most significant; the old are used to non-commercial fuels; Large spatial difference-different habits and accessibility of fuels; With more livestock in home, the use of commercial fuels reduced; The influence of other factors like distance from the rural area to urban/county, the education level, are not significant