Exploring a low carbon development in rural China

The role of households

Wenling Liu

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Exploring a low carbon development in rural China

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Wenling Liu

Thesis

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Preface

This dissertation results from PhD research conducted within the framework of the SURE (SUstainable Natural REsource Use in Rural China) project, which is funded by the Royal Netherlands Academy of Arts and Sciences (KNAW) and the Chinese Ministry of Sciences and Technology (MoST). I would like to express my gratitude for their financial support. I am also grateful to Wageningen University for enabling my studies abroad.

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Beijing, April 2013

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Abbreviations

CCS	Carbon Capture and Storage
COP	Conference of the Parties
DSM	Demand Side Management
EMT	Ecological Modernization Theory
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
kgce	kg coal equivalent
LCA	Life Cycle Analysis
LPG	Liquefied Petroleum Gas
LUTRG	Linkage between Urban-land Taking and Rural-land Giving
MOA	Ministry of Agriculture
NDRC	National Development and Reform Commission
NGO	Non-Governmental Organization
OECD	Organization for Economic Co-operation and Development
PV	Photovoltaic
RE	Renewable Energy
SSB	State Statistics Bureau
UNFCCC	United Nations Framework Convention on Climate Change
VIF	Variance Inflation Factor

Chapter 1. Introduction

1.1. General background

Climate change is the latest, and probably the most serious and significant, global environmental concern. According to statistics of the International Energy Agency (IEA), China's CO_2 emissions from fuel combustion in 2009 ranked first and accounted for 23.7% of the world emissions. But China's CO_2 emissions per capita were at a low level, as shown in Figure 1.1. The growing greenhouse gas emissions have brought mounting pressure from the international community on China to reduce these emissions. But increasingly pressure is also felt domestically.

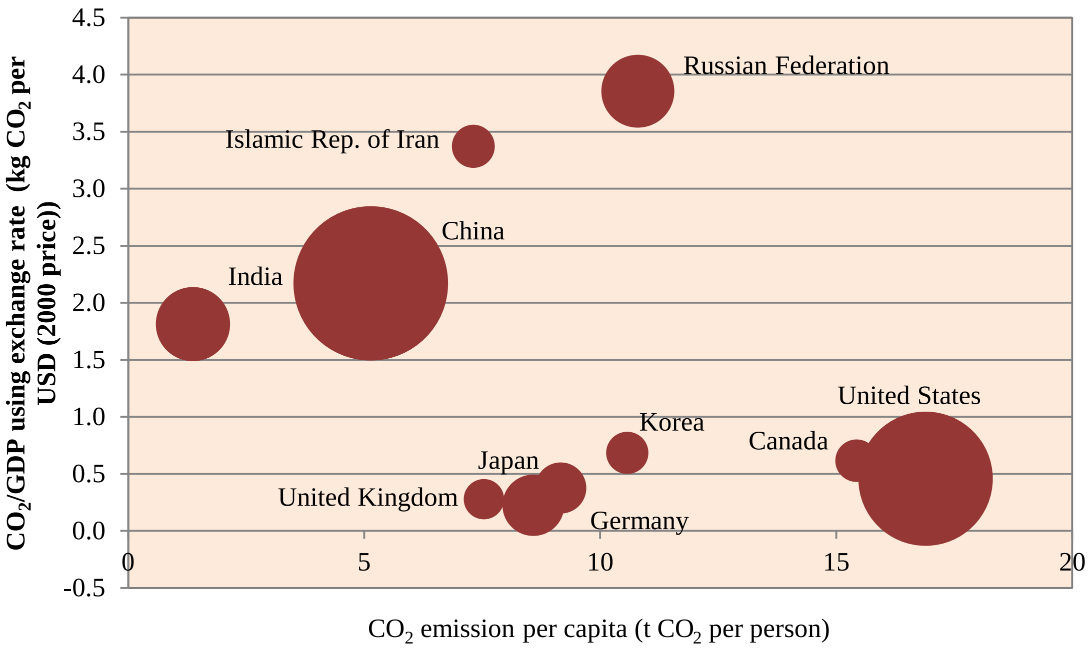

Figure 1.1 CO_2 emission and emission intensities of the top ten emitting countries in 2009

(Data source: IEA, 2011; Size of the circle represents total CO_2 emissions from the country)

The last decade has witnessed a rapid growth of China's Gross Domestic Product (GDP). However this economic growth has been highly dependent on increased energy consumption, which inevitably led to rising carbon emissions. As shown in Figure 1.2, China's GDP increased with an average annual growth rate of 10.5% from 2000 to 2010. At the same time energy consumption increased with an average annual growth rate of 8.4%. A high dependence on coal consumption can be observed in Figure 1.2, with the share of coal in primary energy mix varying from 68% to 71% during this period. Previous research (Zhou et al., 2012) also showed that the dramatic CO_2 increase was mainly caused by the consumption of coal in China. Oil is another major energy source in China; its share in primary energy consumption varied from 17.9% to 22.3% between 2000 and 2010. Along with China's rapid and sustained economic growth, it can be predicted that carbon emissions will further increase if China's energy mix is not drastically changed and/or its energy efficiency per unit of GDP is radically lowered. Strong reliance on an energy structure with a high share of fossil fuels makes it very difficult to mitigate climate change in China.

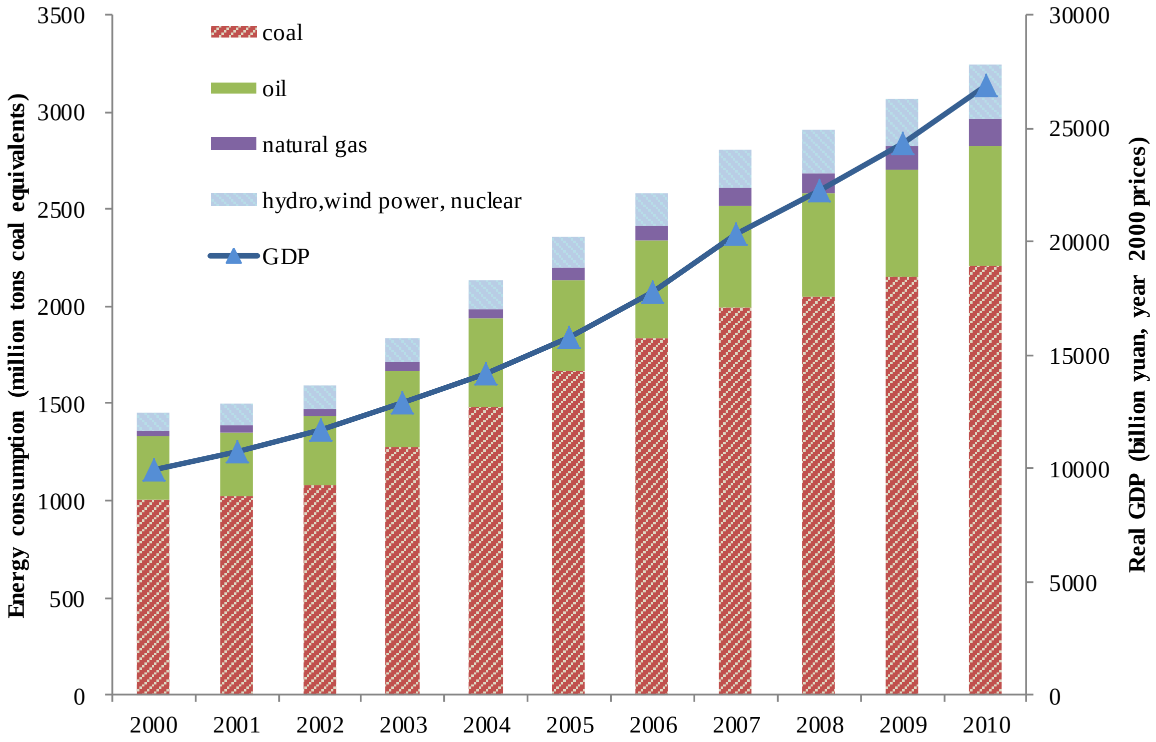

Figure 1.2 China's GDP growth and national energy consumption

(Data source: China Statistical Yearbook, 2011)

1.1.1. China's energy and climate change policies

In recent years the Chinese government has undertaken several new initiatives, both domestically and in international forums, to tackle climate change. Confronted with tough challenges in emission control, China has made major efforts in energy saving and carbon emission reduction by pushing forward domestic sustainable development and committing itself to internationally stringent energy efficiency improvements (He et al., 2012). The 11th Five-Year Plan (2005-2010) included a 20% reduction target of energy intensity per unit of GDP, which resulted in an estimated emission reduction of 1.5 billion tons of CO_2 compared to the scenario with 2005 levels of energy intensity (Wang et al., 2011). The 12th Five-Year Plan sets new targets for the next five years, including a 16% reduction target of energy intensity and 17% reduction target of carbon intensity by 2015. At the Copenhagen 15th Conference of the Parties (COP 15) to the UNFCCC (United Nations Framework Convention on Climate Change) in 2009, China unilaterally pledged the target to cut its carbon intensity per unit of GDP by 40-45% by 2020 compared with 2005 levels.

Various national actions and plans on coping with climate change have successively been developed in China to meet these goals, accompanied by institutional reforms at both national and regional levels. For instance, the National Development and Reform Commission (NDRC) established a climate department in 2008, and a special 'National Energy Commission' was established in 2010. Energy strategies have always been crucially important for climate policies. China's new and renewable energy[1] production has been growing rapidly, together with their share in the energy mix. As shown in Figure 1.2, from 2000 to 2010, the share of new and renewable energy supply in the primary energy mix grew from 6.4% to 8.6%. China has set a target to increase the share of non-fossil fuel energy supply in the primary energy mix to 15% by 2020. Wind, solar energy, and biogas are expected to be further developed, using for example economic incentives such as construction subsidies and feed-in tariffs.

Great efforts have been put into improving energy technologies to enhance energy efficiency, especially in industrial sectors. China promulgated the 'Cleaner Production Promotion Law' in 2003 (Mol and Liu, 2005), followed by a series of relevant measurements such as guidelines, auditing and training. So far cleaner production standards for more than 40 sectors and more than 30 evaluation index systems for industrial sectors have been formulated and implemented (Ma et al., 2010). Energy-intensive sectors such as non-ferrous metal production, coal mining, electricity generation, chemical industry and so on, are set as key industries for cleaner production. The cleaner production program has effectively expedited energy saving and emission reduction within industrial sectors. Other special greenhouse gas

[1] The new and renewable energy indicates all kinds of non-conventional energy utilized based on new and advanced technologies, which may refer to wind energy, solar energy, ocean energy, geothermal energy, biomass, hydrogen and nuclear energy.

(GHG) mitigation projects are initiated as well. For example, state-owned and private enterprises with large GHG emissions have carried out emission reduction projects, such as the '1000 enterprises energy conservation program'. A considerable amount of backward production capacity was phased out, including more than 72,000 MW of small coal-generated power plants and 330 million tons of cement manufacturing capacity (NDRC, 2011). These efforts have resulted in dramatic decreases of energy consumption per unit of major energy intensive products (CPRC, 2012). For instance, coal consumption per unit of thermal electricity generation decreased by 9% during the 11th Five-Year period, comprehensive energy consumption per ton cement decreased by 24.6% and energy consumption per unit of steel refining decreased by 12.8%. Energy efficiency of sectors such as thermal power generation, cement production and electrolytic aluminum production, has come close to standards in OECD (Organization for Economic Co-operation and Development) countries.

In recent years the focus of energy efficiency and greenhouse gas emission reduction efforts and policies has gradually moved to regional and city levels. On the one hand, national reduction targets need to be decomposed into provincial or city targets; on the other hand, it is recognized that cities are producing significant levels of greenhouse gas emissions as a result of the rapid urbanization in China (Dhakal, 2009; Sugar et al., 2012; Liu et al., 2012$_a$). In order to avoid the traditional development modes of developed countries with high-carbon construction and consumption, China has started to explore a new green and low carbon development mode for cities and human lifestyles. In 2010, five provinces and eight cities were set as low carbon province (or city) pilot projects for enhancing the development of local low carbon industrial systems. Guiding a low carbon consumption mode is becoming a focal point during rapid urbanization, as an important element of building a low carbon society in China.

In summary, China's actions in tackling climate change have focused so far on setting strict targets in the context of developing a national energy strategy, and on implementing these in the industrial sector and in urban transportation and buildings. Industrial production is usually considered as the major sector contributing to the high level of greenhouse gas emissions (Zhou et al., 2012). For instance, when we analyze energy consumption per economic sector, as shown in Figure 1.3, the industrial sector is found to account for 71% of the total energy consumption in 2010.

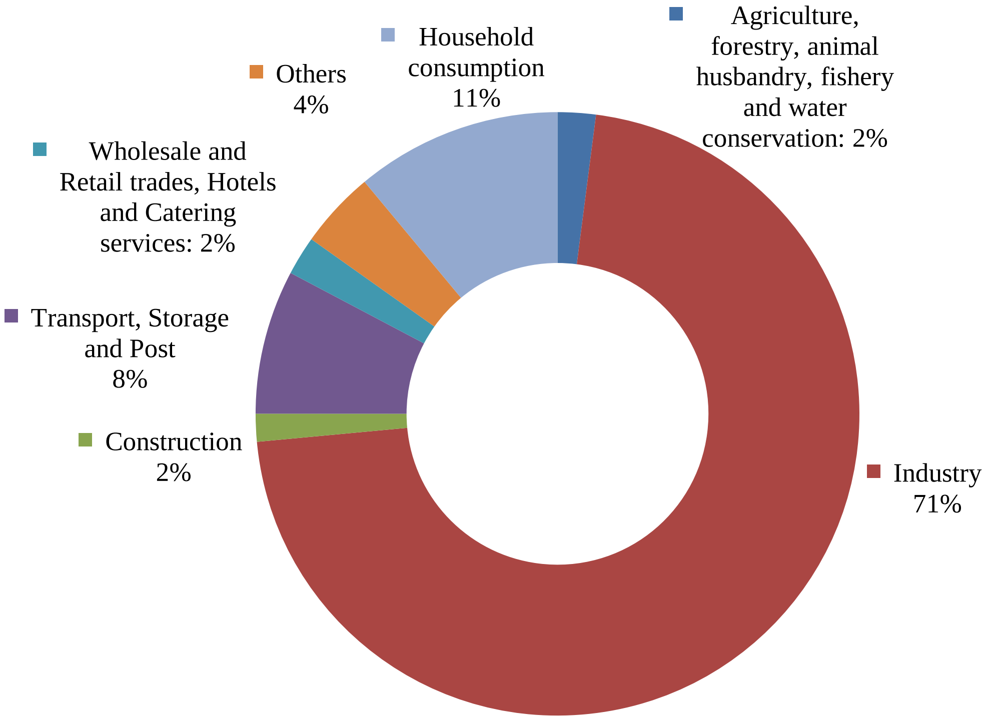

Figure 1.3 Energy consumption by different sectors in 2010

(Data source: China Statistical Yearbook, 2011)

It is also worth noting that household energy consumption accounts for 11% of the energy consumption in 2010. The dominant position of the industrial sector in China's energy consumption and greenhouse gas emission profile should be taken into account in interpreting these data, as it leads to an underrating of the share of residential consumption in energy consumption as compared to developed countries. For instance, final energy consumption by the industrial sector in the world economy only accounted for 28% of total energy consumption in 2010, and for 22% in the OECD countries[2]. Hence, we can expect that the share of domestic energy consumption will increase in China in the near future, considering the pursuit for better and more convenient lifestyles for Chinese citizens. For example, car ownership of urban households has increased more than 24 times (from 0.51 to 13.07 cars per 100 urban households) between 2000 and 2010, while the ownership of air conditioners by urban households in 2010 was 2.6 times higher than in 2000[3].

[2] Calculated based on the data provided by IEA in *2012 key world energy statistics* (http://www.iea.org/publications/freepublications/publication/kwes.pdf)

[3] Data source: China Statistical Yearbook, 2011

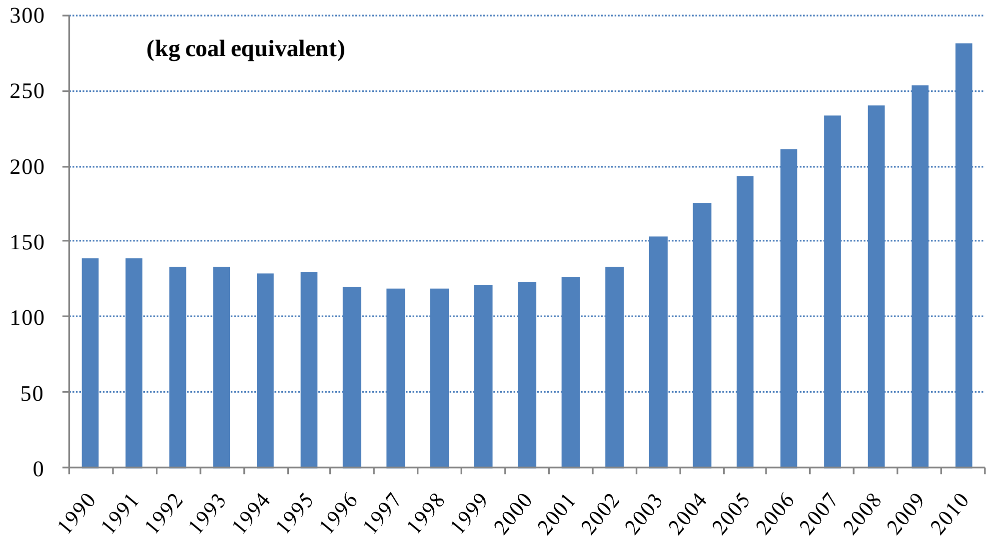

Figure 1.4 Per capita household (commercial) energy consumption in China, 1990-2010
(Data source: China Statistical Yearbook, 2011)

An analysis of the historical change of household energy consumption provides further evidence of this tendency. As shown in Figure 1.4, per capita household energy consumption decreased slightly in the 1990s (coming along with still low levels of consumption, a decline of consumption expenditure of rural residents in the 1990s (Wang, 2003) and the first projects of increasing energy efficiency), but dramatically increased afterwards. The increasing trend may be explained by the rapid urbanization in China, which expands domestic energy demand and also greatly increases CO_2 emissions.

1.1.2. Rural energy consumption

In China, a major gap still exists between rural and urban household energy consumption (see this dissertation, Chapter 2, Figure 2.1). Urban household energy issues are increasingly being addressed and dealt with in the context of discussions on, and measures and policies for, low carbon cities or the low carbon society. However, energy issues in rural China have received little attention so far in comparison with those in urban areas (Zhang et al., 2009). Over the past few decades, the priority of energy security has been given to cities and the industrial sector rather than to rural residents and agriculture. The indifference towards rural areas culminated in many problems with respect to rural energy use in the past, such as a long-term shortage of commercial energy, a heavy reliance on traditional biomass use (wood and straw especially), the wide use of low efficiency energy devices and many kinds of outdoor and indoor air pollution. The situation only changed with the ninth Five-Year Plan (1996-2000), which emphasized the acceleration of rural energy commercialization[4].

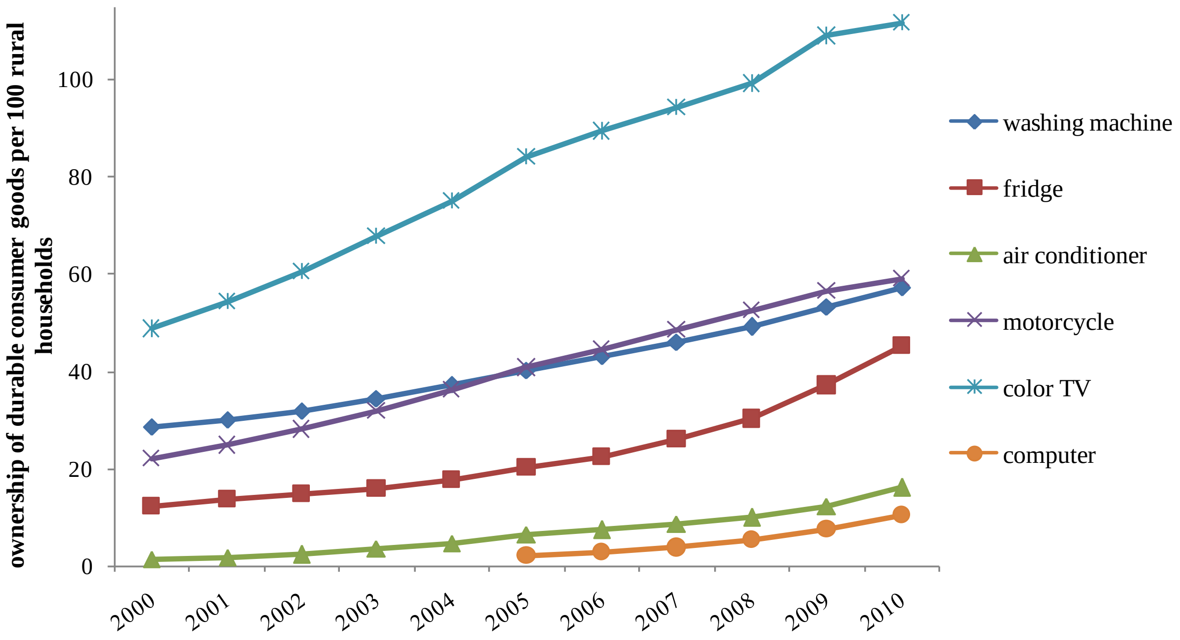

Figure 1.5 Increase of energy related consumer goods owned by rural households
(Data source: China Statistical Yearbook, 2011)

In recent years, China's rural economy has undergone rapid development, accompanied by a substantial and profound change of rural lifestyles and a gradual transition of residential energy use patterns, especially and firstly in the coastal provinces. This resulted in a trend towards a greater variety in energy use among rural residents (see Figure 2.2 and Table 2.1 in Chapter 2). The transition also involved a slight decrease of traditional biomass use and a steady increase of commercial energy use, including coal, oil and electricity (Zhou et al., 2009). The ownership of durable consumer goods of rural households increased strongly over the past decade (Figure 1.5), which came along with changing household daily practices (including cooking, cooling the house, leisure, and transportation) and an increased demand for electricity and oil. Development of the rural economy and improvement of the quality of life of rural residents require incremental reliance on commercial energy. Continually

[4] Rural energy commercialization emphasizes more efficient supply of commercial energy in rural China, and a greater role for commercial or business actors in the energy sector next to or besides the operation of governmental actors and instruments.

increasing commercial energy consumption and energy intensity per capita (Zhang et al., 2009) imply higher GHG emissions in rural China. As a result, rural China is confronted with increasing challenges in contributing to climate change mitigation. Mitigating CO_2 emissions associated with rural domestic energy use and exploring a low carbon transition are therefore crucially important for the climate-change agenda, both academically and in terms of policy making.

Some recent studies have started to pay attention to rural domestic energy consumption and related CO_2 emissions(mitigation) and low carbon strategy issues (Feng et al., 2011; Li and Yan, 2011; Liu et al., 2011; Yao et al., 2012; Zhao et al., 2012). These studies either focused on the impacts of rural energy use on climate change, or discussed concrete cases, for example biomass utilization and biogas construction (Zheng et al., 2010; Zhang et al., 2012), to estimate their possible contribution to mitigating global warming. However, what is lacking so far is academic research that specifies the climate impact of the energy consumption of householders in terms of a variety of specific energy use practices like heating and cooling the home, cooking, or travel. This study explores the possibilities and opportunities for low carbon development in rural China by examining in some depth and detail the emergence and reproduction of domestic practices of energy use, while trying to assess their potential for going through a process of eco-transformation or ecological modernization.

1.2. Ecological modernization as general theoretical perspective

The concept of low carbon development focuses on the relationship between economic growth and the environment, which is often controversial. Ecological Modernization Theory (EMT) is one of the theories which provides input into this dispute and will be applied as theoretical background for this research. Ecological modernization theory was developed in, and against the background of, North-West European countries in the 1980s and 1990s, most notably Germany, the Netherlands, the UK and some Scandinavian countries. EMT is a sociological theory for investigating and understanding how contemporary industrialized societies deal with environmental issues (Mol and Sonnenfeld, 2000; Toke and Strachan, 2006). Based on European experiences and research, EMT has formulated hypotheses specifying how and under what conditions environmental protection can be made compatible with economic growth through decoupling economic growth from negative environmental impacts (CAS, 2007). In general, this theory provides a sociological interpretation of environmental reforms, as well as a new framework for understanding and analyzing environmental policies and ecological transformation. As stated by Mol (2006), in its most fundamental form Ecological Modernization (EM) can be understood as the centripetal movement of ecological interests, ideas and considerations, which results in a process of ecological (environmental) transformation and reform of social practices and institutions. This ecological transformation comes along with technological innovations and structural change, through the conversion of social mechanisms, dynamics and actors, such as new tasks and responsibilities for state and non-state actors (e.g. companies, environmental NGOs (Non-Governmental Organization)), and new state-market relations.

Human-induced climate change, as a significant environmental crisis caused by current modes and levels of production and consumption, most urgently demands solutions to harmonize economic development and climate protection. EMT provides a sociological interpretation of how currently societies deal with climate issues. Developing a low carbon economy has emerged to tackle climate change through exploring an economic development pattern with low energy consumption, low pollution and low carbon emissions. From this perspective, low carbon development is also a concept that fits ecological modernization theory as applied within the domain of climate change. It emphasizes the decoupling of economic growth from its global warming impact, and demands the transformation of social practices, such as energy use behaviour, and institutions at all levels. The essences of a low carbon economy and society is utilizing energy more efficiently, developing clean or renewable energy and pursuing for green GDP, by means of technology innovation, institutional innovation and changes of life styles. EMT provides the theoretical background to understand and interpret current environmental improvements towards a low carbon transition as transformations of social practices and institutions, on the one hand; and it establishes a framework for developing the necessary changes in terms of social mechanisms, social dynamics and actor strategies and behaviour, on the other.

Ecological modernization has been widely discussed in China since the last decade. The concept was first introduced into China at the start of this millennium. Several scholars introduced it in the field of environmental policy (He and Wu, 2001; Huang and Ye, 2001) and discussed the suitability of applying the theory in China. Since then studies focusing on theoretical discussions have been emerging in significant numbers. For instance, Guo and Yang (2006) reviewed the development of ecological modernization and its fundamental notions. Jin et al. (2011) discussed the core target and basic assumptions of the theory.

Theoretical discussions have also been connected with its significance for solving environmental governance problems in China. For example, ecological modernization was applied to Chinese environmental strategy and policy (Mo, 2005), sustainable urban development (Liu, 2006) and low carbon development strategies in China (Liu et al., 2012_b). CAS (2007) applied the concept of ecological modernization to China and evaluated the progress of China in the transformation according to ecological modernization ideas. Finally Zhang et al (2007) compared the Chinese interpretation and use of ecological modernization ideas with the use in western countries.

Besides the more theory-informed discussions, ecological modernization theory has also been applied to a number of case studies on China's environmental transformations in different sectors. Zhang (2002) applied the theory to investigate environmental management of small township & village enterprises in China. Liu (2004) developed a research approach based on ecological modernization to analyze China's societal phosphorous cycles and propose improved phosphorous management. Zhong (2007) used an ecological modernization inspired theoretical framework to investigate the modernization of China's urban water system into more sustainable directions. Liang (2012) elaborated in much detail the ecological modernization as both a social theory and a political program in China, and accordingly established an analytical framework to evaluate payment schemes for forest ecosystem services in China.

Discussions on the ecological modernization from both theoretical and practical perspectives reflect the development of this theory in China, and by the same token imply a progress with implantation of ideas of ecological modernization into the Chinese society. Especially since environmental and climate reforms have moved into the spotlight of societal development in recent years, various concepts and ideas akin to ecological modernization have been emerging in China. Examples are 'the two-type society (resource-conserving & environmental-friendly society)', 'society of ecology harmony', 'low carbon society', 'ecological civilization', and 'circular economy'.

Ecological modernization theory reflects the strategies that western countries were engaged in when developing 'environmental cum economic' reforms since the 1980s. In trying to understand and grasp this development, ecological modernization theory and ideas were not static but developed along the environmental reform trajectories of OECD countries: from an emphasis on technological innovation, to a focus on new dynamics in state-market relations, and up to an ecologically modernized system of production and consumption. However, the ecological modernization of production and the ecological modernization of consumption have not developed at the same pace and in the same way, both in practice and with respect to theoretical reflection (Spaargaren, 2003). Production issues have been a core theme within ecological modernization theory from its inception, while consumption issues have been addressed more extensively only in more recent formulations of the theory (Spaargaren, 2003). Contemporary ecological modernization theory aims to combine both upstream (producers, processing industry, distribution) and downstream (consumers, consumer-organizations) actors and processes when analyzing environmental reform. Thus more recent formulations of ecological modernization theory are addressing the greening of both consumption and production practices and institutions in different parts of the world.

Ecological modernization practice and research in China has followed a similar trajectory. Since the late 1970s, China's economic reform has boosted economic growth with a heavy reliance on energy consumption that supported the industrialization process. This resulted in various environmental problems, such as ecological damage and global warming, which are only paid attention to in recent years. In mitigating climate change and exploring a low carbon development in China, production has always been a central focus, and not surprisingly technological measurements were frequently emphasized. In particular, as discussed in the first section, emission reduction of industrial sectors has been emphasized through technological innovations and cleaner production. Accordingly, ecological modernization research in China has up till now been mostly concerned with industrial production.

In recent years, concern with consumption behaviour has gradually entered China's climate change mitigation interests, together with socio-economic and sociological studies to investigate social factors and drivers behind environmental (mis)behaviour (Démurger and Fournier, 2011; Shi et al., 2009). This study moves beyond a production-oriented focus on ecological modernization to address climate change, and tries to interpret low carbon transition of energy consumption practices of rural households within an ecological modernization theory perspective. As such this study further contributes to the literature on ecological modernization of consumption, but now in the context of the most powerful transitional economy of the world economy.

1.3. Sustainable consumption theories-A conceptual framework

1.3.1. Sustainable consumption theories

Different approaches for analyzing sustainable consumption have been developed within the fields of economics, socio-psychology and environmental sociology. Until now, in many European countries, the policy debate on sustainable consumption and behavioural change is dominated by economists and social psychologists, working primarily from an individualist perspective on understanding and predicting behavioural change (Spaargaren, 2011).

Economic models on consumption behaviour are widely used at various levels of analysis (Deaton, 1992). There are many consumption behaviour theories developed within macro-economics and microeconomics, for example 'the Keynes absolute income hypothesis', 'relative income hypothesis', 'life cycle theory of consumption', and 'revealed preference theory'. Most of these economic theories follow the fundamental hypothesis of the 'rational actor' or the 'economic actor' to judge and explain the formation of certain patterns of behaviour; non-rational or 'irrational' factors are usually not included into the conceptual schemes of economists (Skitovsky, 1976).

Socio-psychological approaches aim to understand how people's thoughts, feelings and behaviours are influenced by the actual, imagined or implied presence of others (Allport, 1985, pp.3). This approach explains human behaviour as a result of the interaction of people's mental states and the social context in which certain action and feelings occur. Socio-psychological approaches have been widely applied into studying and understanding environmental behaviour and discussing sustainable consumption. One typical and quite dominant approach on predicting and changing behaviour is the so-called Reasoned Action Approach (Fishbein and Ajzen, 1975; Ajzen and Fishbein, 1980). The reasoned action theory was developed in the 1970s, and offered a conceptual framework to account for individual behaviour related to health and safety, politics, marketing, the environment, the workplace and many other domains. Application of this perspective in explaining environmental behaviour and designing governance of environmental change has been very dominant from the 1970s onwards.

Figure 1.6 gives a schematic representation of the theory. Specifically, three kinds of belief are distinguished. First, people hold beliefs about the positive or negative consequences they might experience if they perform certain behaviour (Fishbein and Ajzen, 2010, p.20). These behavioural beliefs are assumed to determine people's attitude toward personally performing the behaviour. Second, individual actors form beliefs on the approval or disapproval of their behaviour by important individuals or groups in their lives. These normative beliefs produce a perceived norm, as a perceived social pressure to engage or not engage in certain behaviour. Third, people also form beliefs about personal and environmental factors, which can help or impede their attempts to carry out specific behaviour (Fishbein and Ajzen, 2010, p.21). These are called control beliefs that result in a sense of high or low self-efficacy or perceived control with regard to behaviour. This theory takes intention as the best single predictor of behaviour. Attitudes, perceived norms, and perceived behavioural control determine intention which strongly influences behavioural performance. The stronger the intention, the more likely it is that accordingly behaviour will be performed. However, it is also important to take skills and abilities, as well as environmental factors, into account. This is labeled as actual control, since lack of these required abilities or existing environmental constraints can prevent people from acting according to their intentions. A number of background factors are mentioned in this model, because a multitude of background variables could potentially influence the beliefs people hold. These background factors are classified with dotted arrows in Figure 1.6, as they may in fact influence behavioural, normative and control beliefs but there is no necessary connection between background factors and beliefs.

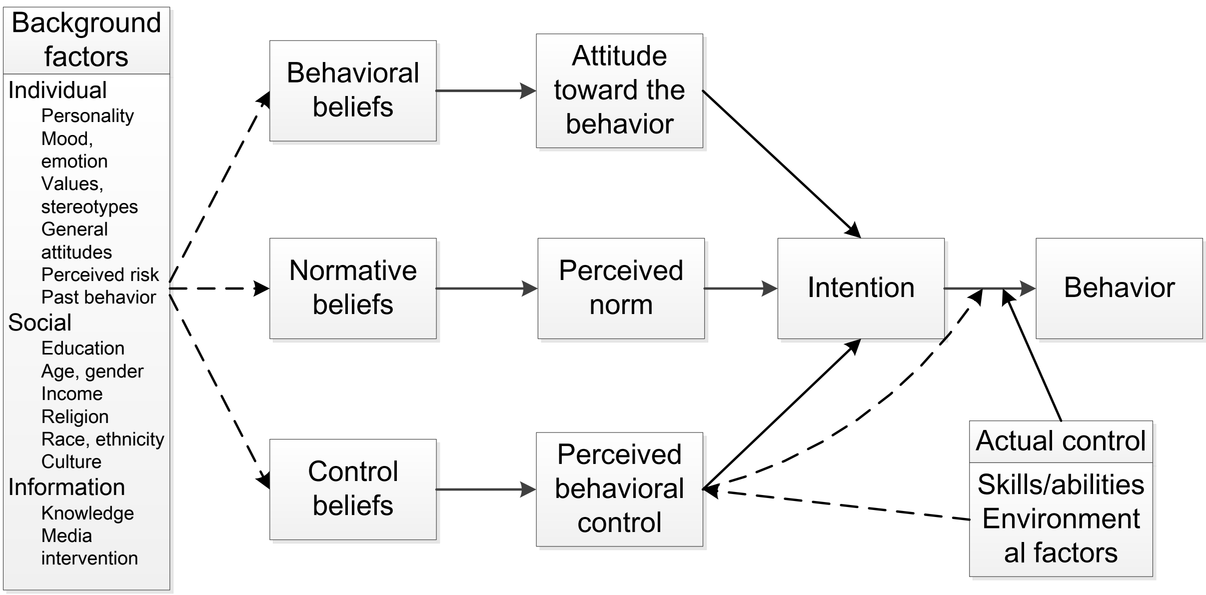

Figure 1.6 Schematic presentation of the reasoned action model (quoted from Fishbein and Ajzen, 2010, p.22)

Partly in opposition to the individual oriented approach, another school of thought was developed within environmental sociology which looks into the issue of environmental behaviour and reform from a different perspective. In the so called systemic or structural perspective, the emphasis is on the contextual factors that influence or even (co)determine environmental behaviours of individuals. In this paradigm, environmental behaviour is regarded to be constrained or locked-in by the socio-technical systems and structures. The policy focus is primarily on producers or states and their strategies as these are determining actor's behaviour with respect to the environment. Accordingly, socio-technological innovations within the production sphere are seen as decisive factors for changing consumption behaviour. Socio-technical systems are regarded as key intervention targets for environmental governance, and key policy instruments are directed at regulating providers/producers rather than individuals, consumers or end-users. A key example of this perspective is found around urban infrastructures. Derived from the systemic or structural paradigm, the system of provision perspective or 'infrastructural perspective' has been developed as an analytical tool/approach to look into the packages of consumption alternatives offered by providers of utility infrastructure in the area of energy, water, transport and waste. These utility infrastructures or systems of provision include utility companies, utility markets, products and services, socio-material networks of provision, technical solutions and so on (Southerton et al., 2004, p.8). Within this perspective, commodities or groups of commodities are expected to be distinctly structured by the supply chain or system of provision. In this perspective there is little room for beliefs and intentions of individual actors or consumers to explain behavioural change in favor of the environment. This system of provision perspective has offered a structural interpretation of sustainable consumption in the context of dominant (infrastructure) providers and producers, and has been applied in a diversity of empirical studies.

Strengths but also limitations of both the individualist and systemic/structural paradigms have been discussed in the literature. The individualist approach was commented to be strong in stressing the importance of the values and beliefs of human agents in co-determining behaviour, but weak in connecting individual action with the 'wider society' (Van Vliet, 2002, p.11). In the individualist approach, the 'situational factors' or 'the environment' often are used as entrance points for including the wider societal context in explaining and predicting behaviour, but it is often seen as a rest category and often remains under-emphasized. On the other hand, the systemic or structural paradigm gives a particular emphasis on 'context' factors, but is being criticized for denying or underrating the crucial role of human agents in processes of environmental change. Citizen-consumers are assumed to behave sustainably if and as far as the proper technologies, infrastructures and (green) products are put into place. However, the uptake and use of the new, more sustainable products, services and infrastructures do not result automatically from their availability. Human agents, their lifestyles, their routines and their previous experiences do matter when predicting the uptake and use of sustainable products and infrastructures (Spaargaren, 2011). Human agents can and do matter for sustainable consumption to happen.

In the context of this debate on environmental behaviour, a third perspective for dealing with (changing) consumption behaviour has been developed within environmental sociology. Within this new paradigm, neither the individual nor the system or structures are in the center of the analysis. Instead of individuals and structures, social practices are offered as key units for research and policy making. This Social Practices Approach takes routine behavioural practices as starting and focal points. By doing so, it offers an integrative (that is: integrating aspects of agency and structure) model to analyze and understand transitions towards sustainable consumption at the level of everyday life. The social practices model looks into possibilities for designated groups of actors to reduce the overall environmental impacts of their normal daily routines. It analyzes the process of reducing environmental impacts of consumption in distinct domains of social life in terms of deliberate achievements of knowledgeable and capable agents who make use of the possibilities offered to them in the context of specific systems of provision (Spaargaren, 2003). In this way, the social practice model takes as its key focus of attention the interconnectedness of systems of provision, social practices and (domestic) agents and their lifestyles.

In this research, the social practice model is applied to the analysis of the energy consumption practices of rural households in China. The conceptual framework is shown in Figure 1.7. The core idea of the social practice model depicted in Figure 1.7 is that the ecological modernization of social (energy use) practices can be organized and analyzed by examining the dynamics of the practices themselves as well as by analyzing (potential) changes in energy provision systems and (potential) changes in the lifestyles of consuming householders. We will shortly discuss the core elements of the model in more detail.

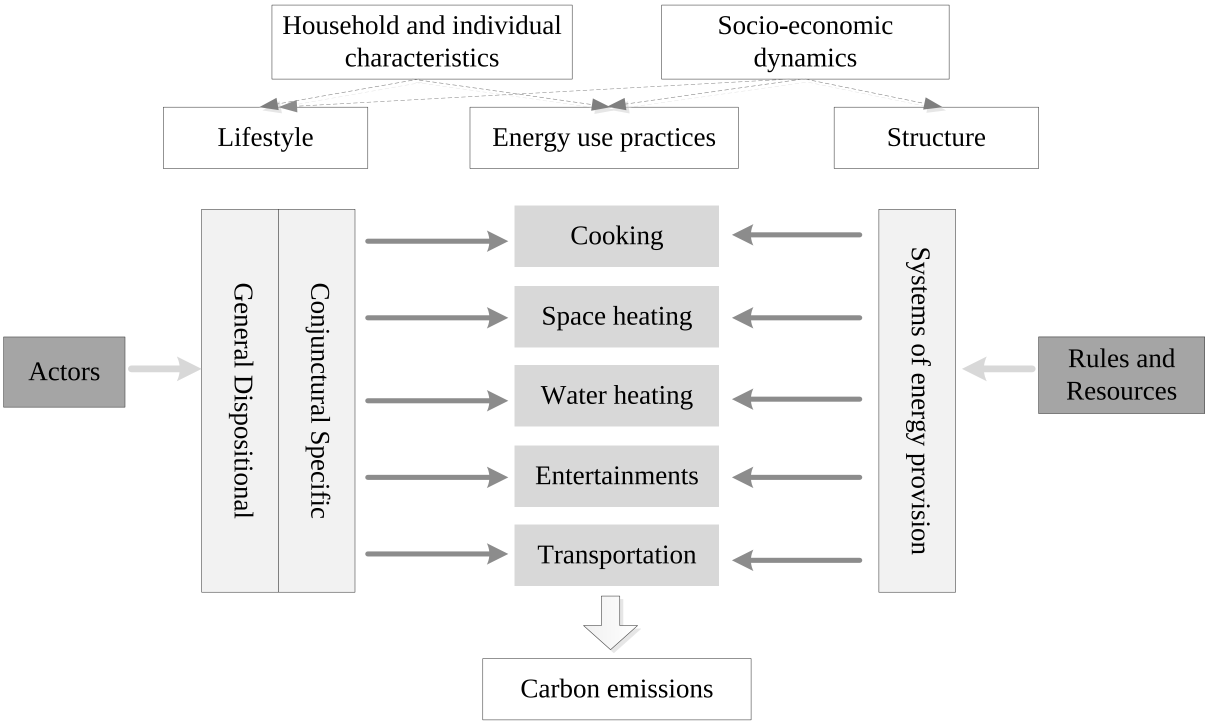

Figure 1.7 A social practice model on rural household energy consumption

Specifically, in the centre of the model there are a number of energy use practices referring to the organized activities of domestic consumers concerning energy utilization; we selected the domestic practices of cooking, heating and cooling the house, daily transportation, and different forms of leisure and entertainment for our research. These practices are the core unit of analysis and they are characterized by their own, particular dynamics which are also historically anchored and mirrored in the lifestyles of householders. This is expressed when householders say "this is how we do the cooking here". This statement is referring not just to the taken-for-granted or routine character of the behaviours but as well to the fact that these behaviours are historically established and the result of socialization into shared social norms about how to cook properly. At the right hand side of the model, a system for energy provision is depicted to indicate the relevance of "utility provision" or the "utility sector" (Spaargaren, 2003; Van Vliet, 2002) for the analysis of domestic energy consumption practices. To explain the practice of cooking, it is important to know how they are shaped by the (non) availability of certain products and energy sources. Also when assessing the potential for low carbon cooking, it is important to know how, by whom and under what kind of conditions more sustainable, climate friendly energy services and products are being made available to (rural, Chinese) households. In this study, we show how household energy use practices in rural China are determined to a large extent by the energy options - biogas, coal, electricity - made available by providers in the energy sector. When analyzing the 'packages of provision alternatives' offered by the energy providers, the system of provision perspective is used as an analytical tool to explain and predict the energy behaviours of rural households. At the left hand side of the model, there is mentioning of the lifestyles of individual householders. Lifestyles refer to the cluster of habits and story lines that result from an individual's participation in a set of everyday life routines that they share with others (Giddens, 1991). It is comprised of the behavioural activities and routines that are performed by households, while also reflecting their members' attitudes, values or worldview (Spaargaren and Van Vliet, 2000). The lifestyle concept can be further subdivided into a general dispositional dimension of the lifestyle of actors on the one hand, and a conjunctural specific dimension on the other (Stones, 2005). The general dispositional dimension of the lifestyle consists of the foundational principles that specific actors adhere to, and which they use throughout a number of behavioural contexts. As such, the concept resembles the concept of attitude, as used in the socio-psychological tradition of research on (environmental) behaviours, and particularly on sustainable consumption, which can be explained to some extent by the 'individualist strategy' perspective. The conjunctural specific dimension of the lifestyles of actors refers to, and is connected with, the specific set of situated practices these actors embrace in everyday life (Spaargaren and Oosterveer, 2010). So when householders say that "they prefer electricity over biogas or coal because they try to improve their overall level of quality and comfort of their daily life", this statement can be said to express both situational (making choices between competing energy options in the context of already established routines) and general dispositional (we like a comfortable life) elements of the lifestyle.

Socio-economic factors situated within the broader context may be major drivers that propel changes within situated behavioural practices, relevant structures and lifestyles of actors at the local levels (Bin and Dowlatabadi, 2005). This is especially true for contemporary China as a country in transition with its rapid socio-economic changes. Thus there are (location-specific) socio-economic dynamics, such as the regional economic level, influencing the three dimensions, as shown in Figure 1.7. Individual and household characteristics also could affect the left hand and middle dimension.

In this section different approaches in the social sciences to analyze consumption behaviour of individuals are discussed. It is argued that both individualist and systemic approaches show particular weaknesses which can be overcome by the use of a third perspective: the social practices approach. A conceptual model was presented to introduce this approach, and the particular elements of the conceptual model were discussed in more detail. With the help of this conceptual model, I am able to confront my research questions in such a way that both aspects of agency and structure are given proper attention when analyzing the patterns of change in rural energy consumption and their related climate impact. Before presenting the research questions, I shortly discuss the particular dynamics of contemporary rural China in applying this social practices model.

1.3.2. Using the practice model to analyze energy consumption in rural China

It goes without saying that none of the elements of the conceptual model - social practices, systems of provision and domestic lifestyles - can be treated as static through time. These elements are constantly changing as a result of factors that are situated at different levels of scale, from the household to the village to the ‘landscape’ of rural China. Throughout rural China, domestic energy consumption practices show a great variety. There exist major differences in these energy consumption practices, originating from socio-economic, cultural, individual and natural (resource) factors and circumstances.

Diverse energy provision systems can be found in rural China, based on diverse energy sources and different forms of organization. For instance, North-South differences in climate lead to different demands for space heating or house cooling; regional differences in terms of socio-economic development to a large extent define the diverse energy infrastructures and organizations. The energy practices of rural households are connected to the alternatives offered by the (regional specific) energy providers. Also the housing styles - the ways in which houses and neighborhoods are designed and constructed - to a large extent determine what kind of energy options households can acquire and use. Both the energy provision systems and the housing construction and design are changing in China in an effort to reduce the climate impact of rural energy consumption. The development of renewable energy is increasingly being promoted in rural China to cope with climate change and rural energy security. Chinese rural households are playing an important role in policies and efforts to reduce the climate impact of domestic energy consumption in rural China. They have to adapt certain energy practices and their lifestyles to the changing conditions of housing and energy provisioning. In other words, the strategies and attitudes (opposition or acceptance) of households towards low-carbon energy consumption are of great importance for the future development of renewable energy in rural China and thus for enhancing (or not) a low carbon society.

The methodological framework was established based on the social practice model to specify the particular ways in which the 'bundles of energy use practices' of rural households in China are related to both the structural context (energy infrastructures and housing design) and to individual factors (attitudes towards low carbon energy uses). With this model, I am able to investigate how household practices affect the climate impacts of rural energy consumption and how they in turn are affected by changing systems of provision in contemporary China.

1.4. Research questions

Rural China is confronted with increasing challenges to address climate change, and these challenges are taken up by policy makers at the moment. A number of research questions are connected to these developments. First, the overall contribution of rural residential energy consumption - in absolute and relative terms - to climate change needs to be specified in quantitative terms. Second, these carbon emissions need to be discussed with respect to the drivers behind the emissions. One of the drivers or elements in (policies for) low carbon development has been given little attention so far: the role of rural households in bringing about the low-carbon transition and transformation of domestic energy consumption. The central objective of this research is to define the existing contribution of rural energy consumption to climate change and to explore the possibilities for low carbon transitions of rural households in China by examining the composition, formation and (potential) transformation of household energy consumption practices. Based on the social practice model for analyzing household energy use, this research investigates in detail a series of energy utilization practices of rural households in China, specifying both the role of systems of energy and housing provision on the one hand and the role of attitudes and lifestyles connected with these practices on the other. More specifically, this study aims to address the following research questions:

- What is the contribution of rural residential energy consumption to greenhouse gas emissions in China?

- What basic attitudes and perceptions do rural residents display towards renewable energy use, and what implications do these have for policies promoting renewable energy development in rural China?
- What is the contribution of different energy use practices of rural households to greenhouse gas emissions in China, and which factors play a role in the (non) development of low carbon domestic energy use practices?
- When considering the provision of housing, in what ways are decisions being made regarding low carbon (behavioural and technological) alternatives for future rural domestic energy consumption practices?

1.5. Research setting and methods

In this section the general research methods and the choice of the research sites are introduced for each of the four research questions (and each of the four empirical chapters).

To evaluate the climate impacts of rural domestic energy consumption (first research question, Chapter 2), macro statistical data are used and analyzed to draw a general picture of rural energy use. Since a variety of energy resources are involved in rural domestic energy use, different accounting methods on carbon emissions are developed based on existing literature and 'IPCC (Intergovernmental Panel on Climate Change) Guidelines for National Greenhouse Gas Inventories'. Data was collected by multiple channels, including sources like the National Bureau of Statistics and the Ministry of Agriculture, to ensure a comprehensive analysis of rural residential CO_2 emissions in China. A Geographic Information System (GIS) is adopted to map emissions of each province. Detailed comparisons of different energy sources and different regions make it possible to identify the major emission sources (energy types) and potential for climate mitigation in rural China.

To study the social acceptance of rural residents towards renewable energy deployment (second research question, chapter 3), a case study was conducted in Zhangqiu county in Jinan, Shandong province, (see Figure 1.8), using a field questionnaire survey as main instrument. Shandong has almost 90 million inhabitants and the third largest GDP in China. Its agricultural GDP ranks first in the country; correspondingly, the rural population accounted for more than 59% of the (registered) provincial population in 2010. Developing renewable energy has been identified as an important provincial strategy, especially for the utilization of renewable biomass energy. Three villages were covered by the survey and a total of 212 valid responses were obtained. The Reasoned Action Theory provides the theoretical and analytical framework. A logit regression model is used to examine the influences of individual characteristics on local social acceptance.

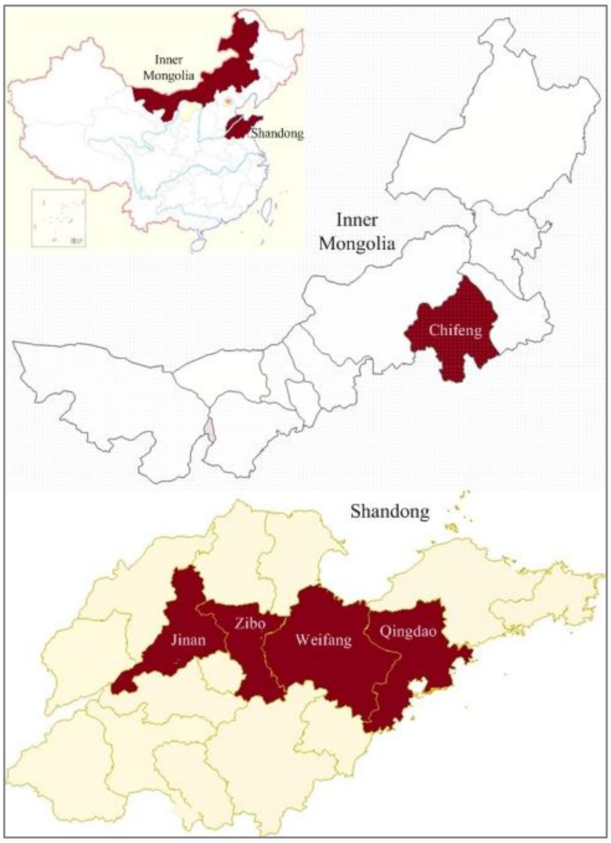

Figure 1.8 Research sites of the three case studies in this research

Case study research is also conducted for an in-depth examination of energy use practices of rural households (research question 3, Chapter 4). Shandong province was selected for this research as a case of a relatively well-off rural area. The per capita net income of rural residents in Shandong was equal to 8,342 Yuan in 2011[5], 19.6% higher than the national average of rural households. Rural households in this province use a variety of domestic energy sources. Recently, renewable biomass energy, solar energy use and wind power generation are actively being promoted, next to conventional sources such as coal, LPG (Liquefied Petroleum Gas) and natural gas. The case study area was set in Zibo (see Figure 1.8). A detailed questionnaire was designed for this survey, and 165 valid household questionnaires were collected in total. A systematic analysis based on the social practices

[5] Data source: Shandong economic and social development statistics bulletin in 2011

model was applied to investigate the nature of the energy consumption practices. Unpacking rural household energy consumption both in terms of the different practices of energy use as well as in terms of the different sources of energy used, this research also presents lifestyle- and context-related factors that help to explain existing differences in domestic energy use practices of households. The evaluation of aggregate energy consumption and carbon emissions of rural households uses a double-logarithmic regression analysis to examine the influence of household characteristics (income, education, etc.) on carbon emissions. A logistic regression analysis is applied to explain the use (versus non-use) of traditional biomass.

The investigation of rural housing provisioning (research question 4, Chapter 5) focuses on three case studies of concentrated rural housing in rural China. The housing development process is investigated in depth to identify major decision makers within different arrangements of housing provisioning and to understand how their decision or strategies are, or could be, linked to low carbon housing alternatives. In-depth semi-structured interviewing is the basic method for collecting and qualitatively analysing data. Three case studies were carried out covering five villages from Qingdao and Weifang in Shandong, and Chifeng in Inner Mongolia (see Figure 1.8). Inner Mongolia was selected as a comparative case to Shandong. Geographically, Inner Mongolia autonomous region is further north than Shandong, wrapped by China's northern border. A large gap in economic development exists between these two provinces. Inner Mongolia is famous for its agricultural output and abundant energy resources. Per capita cultivated land is three times the national average and ranks first in China. It is rich in several kinds of mineral resources, and the reserve volume of coal ranks highest in the whole country. Energy consumption is relatively high in this region in light of the cold climate on the one hand, and convenient coal provision on the other. Thus this province, with a large agricultural (rural) contribution to GDP and with high energy consumption, was selected as a comparison with relatively well-off rural Shandong.

In summary, this research provides an analysis based on macro statistical data and specific in-depth case studies and surveys. Principally the research focuses on energy use behaviour and practices of rural households, and analyses them in relation to socio-economic contexts of energy provision and individual strategies that constitute lifestyles. This allows me to improve the understanding and interpretation of the formation of rural energy use practices and enables me to identify possibilities, opportunities and barriers for a transformation towards a low carbon rural China.

1.6. Structure of the thesis

The thesis contains six chapters. This first chapter has provided general background information and set the problem of the research, introduced the theoretical underpinnings and conceptual framework and formulated the research questions and general methodology. Chapter 2 gives a comprehensive analysis of rural residential CO_2 emissions in China, and employs a geographic information system (GIS) to map emissions of each province. By identifying the major rural emission sources, this chapter provides a basis for understanding the potential for greenhouse gas emission reduction in rural China. Chapter 3 pays attention to individual preferences in renewable energy deployment in this process. Rural social acceptance of renewable energy diffusion in rural China is evaluated, followed by an examination of individual characteristics that explain attitudes of rural residents to renewable energy. Chapter 4 examines household energy use and its carbon emission impacts. To assess the potential for low carbon development, overall CO_2 emissions of rural households are estimated, followed by a more in-depth description and characterization of the different energy use practices within the households. Chapter 5 takes a more structural perspective and looks into three case studies of concentrated rural housing provisioning. Housing development processes are investigated in depth to identify major decision makers within different arrangements of housing provisioning and to understand potential participants in developing low carbon rural housing. Finally, Chapter 6 summarizes the empirical research findings, assesses these findings against the general literature and discusses implications of the research results for policy making and further research.

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Chapter 2. Rural residential CO_2 emissions in China: where is the major mitigation potential?[6]

Abstract

Despite high-speed economic growth in recent decades, rural China is still confronted with persisting poverty, alongside energy shortages and environmental degradation. In tackling climate change, carbon emissions from rural energy use have been given little attention up till now. This paper provides an analysis of rural residential CO_2 emissions in China based on diverse accounting methods, and employs the geographic information system (GIS) to map emissions of each province. Identifying the major emission sources could provide a basis for understanding the potential for greenhouse gas emission reduction and proposing related policy recommendations. The results showed that the largest GHG mitigation potential can be found at traditional biomass use among residents. Four emission reduction policy strategies are identified: (i) shifting to commercial energy; (ii) furthering the use of decentralized renewable energy options; (iii) commercializing biomass energy via biomass power generation, biomass briquettes and biogas production; (iv) improving the combustion efficiency of traditional biomass use in household appliances. Differences in resource endowment and local economic conditions created varied levels of rural residential greenhouse gas emission, the related mitigation potential, and the kinds of strategies and policies that need to be developed in the Chinese provinces.

Key words:

CO_2 emission, rural residential energy, biomass

2.1. Introduction

Nowadays, tackling climate change has become one of the largest challenges facing the world. For the last several years China has been one of the largest contributors to global greenhouse gas emissions. However, addressing climate change in China mainly focuses on urban areas, transport, and industrial energy needs. Energy issues and GHG emissions in rural

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China have received little attention over the past years (Zhang et al., 2009a). In the past three decades, along with remarkable high-speed development, continuously increasing total energy consumption and per capita energy consumption have also led to increases in GHG emissions in rural China (Zhang et al., 2009b). Meanwhile, compared with urban areas, rural households have suffered long-term energy shortages, and rural populations still depend heavily on conventional biomass energy for cooking, heating and other domestic functions. Additionally, energy-induced environmental problems are posing threats to rural public health. Therefore, rural energy issues have caught the attention of policy makers, particularly in the current context of addressing climate change and promoting low carbon development. Within rural energy, residential energy is of great importance as it is the primary component of rural energy consumption and directly relevant for residents' quality of life. Due to the complexity of rural energy issues, no systematic evaluation of rural residential carbon emissions has taken place and a scientific inventory or accounting guideline is still absent. It is crucial to first understand general issues related to rural energy consumption and carbon emissions.

Rural residential energy use includes commercial energy sources and non-commercial energy sources. The former mainly refers to coal, gasoline, diesel, LPG, and electricity; the latter mainly consists of agricultural crop residues, firewood and biogas. Previous studies on CO_2 emission from energy consumption or fuel combustion in rural areas have focused on commercial energy consumed, while emissions from biomass combustion have been neglected. Biomass is usually regarded as a carbon neutral source. For instance, in a part of the Life Cycle Analysis (LCA) community, a convention has been established which assumes that CO_2 emissions need not to be counted if emitted by biomass. This is based on the argument that the creation of that biomass has removed as much CO_2 as is emitted during its combustion. However, the logic of such a practice is criticized by Rabl et al (2007), illustrating the absurd implications and conclusions of this type of thinking. Rabl and his colleagues (2007) use the example of CO_2 emitted by burning a tropical forest. If not counted this would equalize the climate impact of burning a forest and preserving it, which is obviously wrong. Not counting biomass emissions would also ignore the mitigation effects of some technologies or policies, such as Carbon Capture and Storage (CCS) being included or "polluter pay" policies that are designed for taxing end-use emissions. The UK Environmental Agency (EA, 2009) also casted doubt over the CO_2 emission neutrality of biomass power, which proved that carbon emissions of biomass use depends on a series of links, including the producing and processing (harvesting) of biomass, transportation, energy conversion efficiency and so on. Thus, the argument that biomass is a zero-emission source is too general and not valid. Consequently, it is necessary to estimate emissions from biomass combustion at the last stage of its life cycle.

Previously, some attention was given to CO_2 emissions of rural biomass combustion in China (Zhang et al., 2010; Wang and Feng, 2004), but only simple estimations were provided. This research provides an explicit calculation on rural residential emissions from the end use of energy, and gives an overview of rural residential energy use and its carbon emissions. Covering a range of fuels, whether from commercial or non-commercial energy sources, can remove some of the uncertainty in estimates of China's GHG emissions from fuel combustion and also provide a basis for understanding the potential for GHG emission reduction in the household sector. The following section first gives an overview of China's rural energy consumption for livelihood and related policies. Section three elaborates on emission accounting methods for different energy sources, followed by the section four which presents CO_2 emission estimation results, focussing on provincial differences. Policy implications and conclusions are discussed in the final two sections.

2.2. Overview of rural residential energy consumption

2.2.1. Rural residential energy use

In recent decades, China's rural economy has undergone rapid development, accompanied by a substantial and profound change of rural lifestyles and a gradual transition of residential energy use patterns. However, poverty persists alongside energy shortages and environmental degradation in rural China. Different from urban residential energy use, a shortage of commercial energy and heavy dependence on conventional biomass use contribute to the persistence of rural poverty. Generally, rural residential energy utilization has some distinct features.

Despite the high speed growth of commercial energy consumption, rural energy usage is still very primitive compared to urban energy usage. Due to the secondary position of rural areas in Chinese development strategies in the past decades, the priority of energy security was always given to cities and the industrial sector rather than to rural residents or agriculture. Following a lack of accessibility to commercial energy, rural residents' daily energy supply has relied strongly on local available biomass fuels in recent decades. Since the reform and opening up policy was initiated in 1978, the continuous increase in commercial energy use among rural residents has not closed the gap between rural and urban levels of commercial energy use. As shown in Figure 2.1, per capita commercial energy consumption of rural residents is only half of that of urban residents (a rural value of 184 kgce (kg coal equivalent) compared with an urban value of 336 kgce in 2009). However, when taking biomass fuel combustion into account, rural per capita energy consumption is actually higher than urban per capita energy consumption. Since 1998, rural per capita energy use has increased at a steady rate of 5.8%, from 378 kgce to 518 kgce in 2007. As part of that increase, conventional biomass use per capita increased on average of 4.5% per year. Similarly during this period, both rural and urban commercial energy consumption showed stable growth, at a rate of 9.5% and 4.5%, respectively. Overall, rural residential energy consumption has presented much higher growth rates than the urban equivalent especially since the beginning of this millennium, but heavy dependence on conventional biomass use still severely prevented the improvement of rural energy usage.

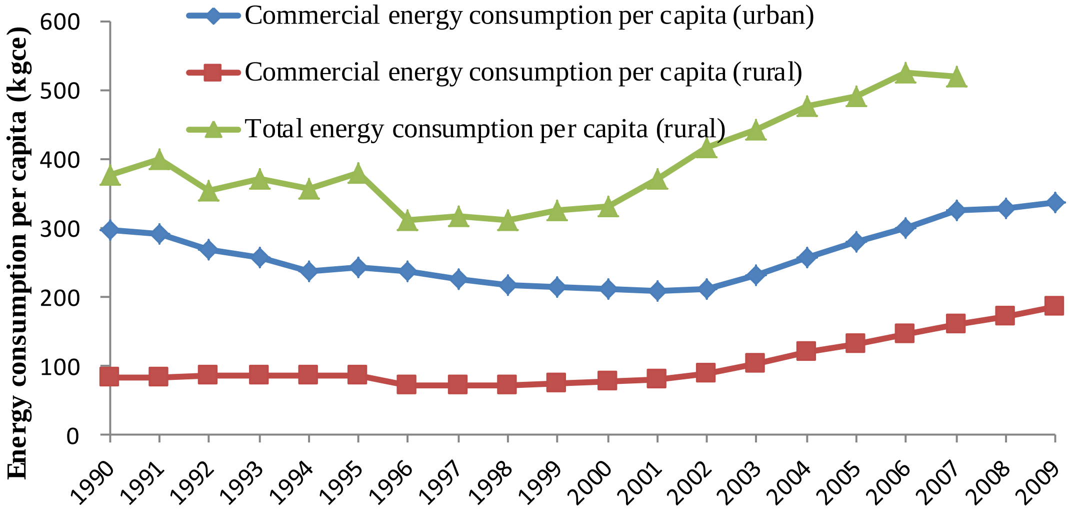

Figure 2.1 Rural and urban residential energy consumption per capita
(Note: data on non-commercial energy consumption in 2008 and 2009 is absent;
Data sources: China Energy Statistical Yearbook 2010 and Zhang et al., 2009$_a$)

China uses a large proportion of biomass in the traditional way - biomass is directly combusted for energy use among rural residents. In fact, most biomass energy use is directly combusted for end use, without conversion into modern energy carriers, which typically brings greater adverse environmental, health and social impacts. The directly combusted wood and agricultural residues are mainly used for cooking, water heating and space heating. Sometimes one device could serve for a few end-uses, for example, stoves linked with kangs[7] could be used for cooking (water heating) at the mean time of heating space, besides this, biomass fuels may also be used in kinds of standalone stoves (e.g. for cooking). Environmental impacts (e.g. carbon emissions) of traditional biomass combustion vary by different devices used and different seasons, as shown by Wang et al (2009_a) (see Table 2.3, footnote. a). Generally speaking, the combustion systems used for these fuels tend to be inefficient and lead to both high indoor and outdoor air pollution (Wang et al., 2008). For instance, a large-scale field survey in 2006 showed that kangs were found in nearly 85% of the rural homes in northern China, where it is mostly cold and dry in the winter with a 6-9 month heating season, as well as in Shandong and Henan provinces. Heat efficiency of kangs and biomass stoves was only around 30% (Zhuang et al., 2009). It should be noted that not all agricultural crop residues (like straw) are used as residential fuels in rural areas. More agricultural residues are directly burned in the open field (Yan et al., 2006), which has resulted in serious environmental consequences including greenhouse gas emissions. Since 1997, governmental regulations and laws have been introduced to forbid the field burning, and farmers are also encouraged to return straw to soils with subsidies. The ways how the crop residue is disposed of determine different impacts on carbon emissions. Returning straw to soils may work as a carbon sink as well as agricultural fertilizer, but both residential and field burning of crop residues are important sources with significant impacts on global climate change (Andreae and Merlet, 2001). However, in this paper we try to make an overall estimation of rural residential CO_2 emissions based on the data of end use of all kinds of fuel sources for household daily life. We would not take other dispositions of biomass (except domestic burning of biomass fuels) into account in the following analysis.

In recent years there has been a trend towards greater variety in energy use among rural residents. A transition of household energy use patterns involves a slight decrease of traditional biomass use and a steady increase of commercial energy use, including coal, oil and electricity. Figure 2.2 illustrates a slight decline of the proportion of firewood since 2002, while both electricity and oil consumption increased annually. However, the changes reported in Figure 2.2 are not as large as those depicted in Zhang et al (2009_a), who found a much stronger decrease of biomass use and increase of coal, oil and electricity when assessing the entire rural energy consumption structure. Clearly, rural residential energy use shows less

[7] A kind of heatable brick (or mud) bed in Northern China

change towards commercial energy sources than rural energy consumption for agricultural and industrial production. The other obvious tendency is a rapid deployment of renewable energy among rural households. As shown in Figure 2.2 and detailed in Table 2.1, the proportion of biogas use in rural residential energy consumption rose from 0.6% in 2000 to 2.2% in 2007. Rural biogas output increased from 2.59 billion m^3 in 2000 to 11.8 billion m^3 in 2008. Besides, solar energy is being widely applied on roofs and in backyards of rural households, where there are abundant solar potentials. The area of solar water heater installation increased from 11 million m^2 in 2000 to 47.6 million m^2 in 2008 (cf. Han et al., 2010). The solar cookers installed increased three fold from 2000 to 2008.

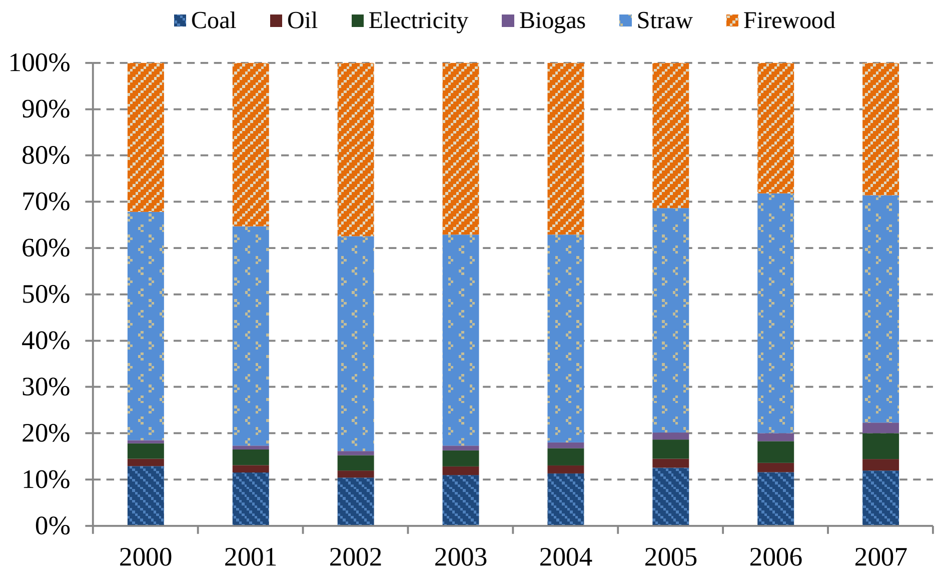

Figure 2.2 Source structure of rural residential energy use

(Data sources: China Energy Statistical Yearbook (2001-2008))

Table 2.1 Development of rural biogas and solar energy in China

Items	2000	2001	2004	2005	2006	2007	2008
Rural biogas output (billion m^3)	2.59	2.98	5.57	7.29	8.36	10.17	11.84
Annual growth rate (%)	-	15%	23%	31%	15%	22%	16%
Area of Solar water heater installation (million m^2)	11.1	13.2	28.5	32.1	39.4	42.9	47.6
Annual growth rate (%)	-	19%	29%	13%	23%	9%	11%
Solar cookers installed(thousand unit)	332.4	388.6	577.6	685.6	865.2	1118.8	1356.8
Annual growth rate (%)	-	17%	14%	19%	26%	29%	21%

Data sources: China's Rural Energy Statistical Yearbook (2001-2008); China New Energy and Renewable Energy Statistical Yearbook 2009.

2.2.2. Related rural energy policies

Until recently, due to the decentralized supply of rural energy and the continuous transformation of rural energy management institutions, rural energy policy and administration have lacked a specific strategic framework. Rural energy policies have been developed by different sectoral institutions and elaborated in different sectoral or industrial policies. Usually rural energy development involved electricity enterprises, the agricultural sector, the forestry sector and the Development and Reform Committees. Additionally, unlike rural energy policy systems in other countries, rural energy development in China has been separated from urban energy development, and has not been included in the national energy strategy (Zhang et al., 2011). Rural energy related polices have gone through a series of changes at different stages of development.

Before the 1990s, rural areas of China suffered from energy shortages. Due to governmental priority to meet urban and industrial energy demands, rural energy management and development was mainly focused on rural local energy resource endowments. The development of biogas, firewood forests, small hydro power, small coal mining industry and firewood or coal-saving stoves was key objectives during this period. However, because of a lack of technology and funds, some of these energy development strategies were not effectively deployed, such as the use of biogas. While small coal mining industries were encouraged, their irregular mining practices led to the waste and depletion of coal resources and to serious air pollution. In general, rural energy policies lacked the necessary support for full policy implementation (Zhu, 2007).

Since the 1990s, national energy security has been a high priority on the agenda of the national policy. Then rural energy was gradually taken into account as an important component of China's national energy security. The ninth Five-Year Plan (1996-2000) for national economic and social development (with medium-term objectives for the year 2010) promoted the diversification of rural energy supply, in order to accelerate the process of rural energy commercialization and the development of rural energy industries. Since 1998, the administration and supervision of small coal mines have been strengthened, many of them closed or merged. Around 180 billion RMB (around 28.4 billion USD at current exchange) has been invested in upgrading rural power grids (Zhu, 2007). The 2005 Renewable Energy Law strongly emphasized the deployment of renewable energy in rural areas.

In recent years, since climate change is a priority in global agendas, the catch phrase "less emission and more sequestration" has become an important development target of rural energy policy. China has introduced some policies and measures to promote the development and utilization of biomass through biomass power generation, biogas, and biomass briquettes, and to strongly enhance the deployment of wind power, solar energy, and geothermal energy. Additionally, China emphasized the increase of terrestrial carbon storage, and the development and protection of forest for ecological and biomass energy purposes. According to the Mid- and Long Term Development Plan on Renewable Energy (NDRC, 2007), nearly 70% of rural households should use renewable energy to satisfy at least some of their daily energy demand by 2020.

With the increasing need to address issues of rural development and global warming, the focus of rural energy policy has partly moved to the development and utilization of renewable energy. Nevertheless, currently rural energy is still treated differently within national commercial energy supply, and is not fully included in the national energy strategy. China has introduced many renewable energy related policies, laws, and funding, but there still lack specific and effective measures and support instruments for their implementation in rural areas.

2.3. Accounting methodologies

2.3.1. Data sources

Rural energy use involves diverse types of fuels, including those used for traditional biomass combustion. There is an inherent problem of data availability in rural energy statistics. Data associated with rural energy is collected and compiled by multiple sources and through different channels. Thus due to the varied statistical standards and methods, there are substantial differences in the data. In China, data associated with rural energy is mainly processed by the State Statistics Bureau (SSB) and the Ministry of Agriculture (MOA). To ensure consistency in data use and statistics, we mainly relied on energy data from the China Energy Statistical Yearbook (compiled by SSB). When it was not available from SSB, data from MOA was used. The China Energy Statistical Yearbook stopped providing statistics on traditional biomass consumption after 2007. Although more recent data has been presented by other sources (such as the China New Energy and Renewable Energy Statistical Yearbook (2009, initial issue)), there were inconsistencies with statistics from SSB due to the different channels and methods of data collection and processing. Therefore in this paper, we only used data associated with biomass consumption until 2007 in order to give an accurate assessment on rural-urban differences and spatial diversity.

2.3.2. CO_2 emission accounting for commercial energy

CO_2 emission from commercial energy (fossil fuels) is a primary contributor to climate change. For accounting commercial energy emissions in rural China, we adopted the most widely used methodology provided by IPCC (2006), as shown in the following:

$$E_h = \sum_{i=1}^{n} EF_i \times C_i \tag{1}$$

$$EF_i = CEF_i \times NCV_i \times OR_i \times 44/12 \tag{2}$$

Where:

E_R: residential CO_2 emissions (t);

EF_i: CO_2 emission factor for fuel *i* (t CO_2-*eq* per fuel unit);

C_i: consumption of fuel *i* (fuel unit);

CEf_i: carbon content of the fuel *i* (t C/TJ);

NCV_i: net calorific value of fuel *i* (TJ per fuel unit);

OR_i: oxidation rate of fuel *i* (percent).

It should be noted that the oxidation rate of coal and coke combustion in rural areas was assumed to be 80% (Zhang et al., 2008_b), to distinguish it from urban combustion efficiency (which was assumed to be 100% following the IEA practices of using 100% as the default value in its calculations).

Since we estimate CO_2 emissions based on end-use energy consumption, emissions from electricity use is also taken into account. Calculation of emissions from electricity use complied with Eq. (1). We calculated the CO_2 emission factor from electricity consumption according to coal consumption of power supply in each year, as shown in Table 2.2. Due to efficiency improvement at thermal power plants, average annual coal consumption for each unit of electricity supply has been decreasing. By taking this variable, multiplied by the proportion of thermal power generation in each year and by the emission factor of coal equivalent (2.45 t CO_2-eq/tce), we obtained the emission factor of electricity consumption for each year. The calculation method is shown as follows:

$$EF_{Electricity} = EF_{ce} \times C_{ce-s} \times P_{thermal} \tag{3}$$

Where:

$EF_{electricty}$: emission factor of electricity in each year (t CO_2-eq/kWh);

EF_{ce}: emission factor of coal equivalent (t CO_2-eq/tce);

$CF_{ce\text{-}s}$: coal equivalent consumption of power supply in each year (kgce/kWh);

$P_{thermal}$: proportion of thermal power generation in each year (%).

Table 2.2 Key parameters for a calculation of emission factor of electricity consumption

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Coal consumption of power supply (g/kWh)	392	385	383	380	376	370	367	356	349	340
Proportion of thermal power generation (%)	81.0	81.2	81.7	82.9	82.6	81.5	83.3	83.3	81.2	81.8

Data sources: China Power Yearbook (2001-2009).

Similarly, emissions from heat energy use should be estimated since we calculate emissions of urban residential energy use as a comparison. Different from rural households, heat energy is one of the main energy sources used by urban residents, especially in northern parts of China. Calculating emissions from heat energy use also follow Eq. (1). Its emission factor was calculated based on Eq. (4), where boiler efficiency and efficiency of heat supply network were assumed to be 65%[8] and 90%[9], respectively.

$$EF_{Heat} = EF_{ce} \times CF_{heat-ce} / (E_{boiler} \times E_{network}) \qquad (4)$$

Where:

EF_{ce}: emission factor of coal equivalent (2.45 t CO_2-eq/tce);

$CF_{heat\text{-}ce}$: conversion factor of heat to coal equivalent (kgce per unit heat);

E_{boiler}: efficiency of heat boiler (%);

$E_{network}$: efficiency of heat supply network (%).

[8] http://www.ranshaoji.net/news/guoluzhishi/1/zixun665.html
[9] It is set according to an interview with officials from the Chinese Ministry of Construction.

2.3.3. CO_2 emission accounting for traditional biomass combustion

Little research has been carried out on the emission inventory of rural biomass combustion. Although default emission factors of straw and firewood have been provided by IPCC, diverse utilization patterns (various stoves) in rural China make it difficult to estimate reasonable values for combustion efficiency. Using the same accounting method that is applied for commercial energy sources (coal, oil, gas) would lead to significant deviation and uncertainty. Therefore, we tried to determine emission factors of different kinds of biomass based on a literature review. There exist some different studies on the emission inventory of biomass combustion in China's rural areas. Most of these studies provide empirical results obtained from experiments and practical measurements. Such results could shed light on the situation of rural emissions, especially the findings from experiments in rural China.

Table 2.3 lists the results of our review of recent studies concerning CO_2 emission factors of firewood and three types of straw used in rural China. Within these studies, experiments were designed in various provinces, including Shandong, Hebei, and Beijing. We averaged the results of these studies for each kind of biomass fuel, and adopted the final value as the average national emission factor per biomass fuel (listed on the top of Table 2.3). From the China Energy Statistical Yearbook we can only obtain the amount of straw and firewood consumption; however what kind of straw and how much of each kind was consumed are not mentioned. In order to ensure accuracy of emission accounting, we divided the straw consumption data into respective amounts of wheat, rice and corn straw use. Zhang et al (2008$_a$) and Gao et al (2002) were taken as references for estimating the percentage of each of the three types of agricultural crop residue burned as domestic fuel (for the estimated results see Table 2.4). Zhang et al (2008$_a$) (also taking Gao et al (2002) as a reference) sets percentages for 2004, but as the provincial agricultural structure has not changed dramatically, it will also reflect the amount of rice, wheat and corn straw used for cooking and heating in 2007 within each province.

Table 2.3 Studies on CO_2 emission factor of types of biomass fuels in China (g CO_2/kg fuel)

Country	Area	Crop residue			Wood	Sources	Methodology
		Rice straw	Wheat straw	Corn straw			
Value in this paper:		883.5	1212.8	1278.7	1481.8	Following literatures	
China	-	976±58 (stove)	stove-Apr:675.7±87.3 stove-	stove-Apr:704.3±80 stove-Jan:1313.7±1	stove-Apr:1171.9±87.3 stove-	Wang et al (2009)*	Experiment

			Jan:1147.6±123	1 kang-Sep:1499.7±33 kang-Jan:1544.2±6.4	Jan:1490.9±23.5 Kang-Sep:1568.43±55.6		
China	Shanghai, Hebei	791.3±12.5	1557.9±85.8	1261±59.9	-	Zhang et al (2008$_a$)	Experiment
China	Shandong		1470±46	1350±16	-	Li et al (2007)	Experiment
China	-		1225±101		1658±46	Yan et al (2006)	Literature
China	Beijing		1320		1410-1630	Zhang et al (2000)	Experiment

*. This research included measurements from five biofuels and two stove types in the months of January, April and September.

Table 2.4 Estimated amount of traditional biomass consumption for residential use in each province in 2007 (10^4t)

Area	Firewood	Rice straw	Wheat straw	Corn straw	Area	Firewood	Rice straw	Wheat straw	Corn straw
China	18216.9	7943.1	8485.9	17568.5	Henan	847.9	68.0	1424.3	697.1
Beijing	48.9	0.3	9.3	29.1	Hubei	992.1	960.4	259.6	385.0
Tianjin	105.4	6.5	71.7	230.4	Hunan	1004.4	486.2	8.3	96.9
Hebei	892.4	13.1	715.2	1103.2	Guangdong	1436.2	630.8	1.9	91.9
Shanxi	230.7	0.7	310.1	847.1	Guangxi	1714.6	1631.6	4.1	673.7
Inner Mogolia	280.4	15.2	46.6	934.2	Hainan	172.0	68.0	0.0	9.4
Liaoning	810.1	145.9	5.6	1209.0	Chongqing	506.7	281.2	82.6	364.1
Jilin	304.7	77.1	2.5	1217.3	Sichuan	1354.4	1424.7	904.5	1607.4
Heilongjiang	347.5	555.8	57.4	1759.1	Guizhou	1645.1	102.1	36.4	228.5
Shanghai		0.0	0.0	0.0	Yunnan	1082.0	170.2	58.1	333.0
Jiangsu	181.3	881.7	837.8	397.6	Xizang	22.0	0.2	19.7	2.1
Zhejiang	268.5	248.3	17.5	26.5	Shanxi	726.3	40.1	460.8	636.8

Anhui	821.8	894.6	1308.4	776.5	Gansu	375.2	1.8	294.8	387.3
Fujian	540.1	141.1	1.6	10.1	Qinghai	33.4	0.0	127.5	0.0
Jiangxi	580.2	417.9	1.9	6.2	Ningxia	14.0	8.9	39.9	92.7
Shandong	480.9	28.3	1246.9	1646.0	Xinjiang	397.8	16.8	199.3	327.5

Data source: China Energy Statistical Yearbook 2008.

2.4. Differentiated rural CO_2 emissions from energy

2.4.1. A comparison with urban residential carbon emission

The total CO_2 emission from residential commercial energy use, both urban and rural, was around 500 million tons in 2007, which accounted for about 8% of the national CO_2 emissions (according to IEA report[10], China emitted 6000 million tons of CO_2 from direct fossil fuels combustion in 2007, accounting for 21% of the global CO_2 emissions). When taking emissions of traditional biomass combustion into account, the conclusion is quite different. As shown in Figure 2.3, CO_2 emissions per capita from commercial energy use kept rising annually for both urban and rural areas. CO_2 emissions per capita from traditional biomass combustion also increased gradually, but the rate of increase slowed down in recent years. Obviously when CO_2 emissions from biomass are included, the rural emission level is much higher than the urban level. In recent years, the gap between urban and rural commercial energy emissions seems to be narrowing. In terms of the internal structure of rural emissions, non-commercial energy use has contributed the most, about three times as large as commercial energy emissions. Commercial energy use in rural areas is still at a rather low level. Historical trends in China, as well as in other countries, have shown that commercial energy use in rural areas keep increasing along with rural economic development and living standard improvement. Rural residential emission mitigation based on reductions in commercial energy use is basically impossible. However, the large amount of emissions from biomass combustion imply large mitigation potential in rural areas, through tactics such as shifting to other (commercial, renewable) energy sources.

[10] http://www.iea.org/stats/index.asp

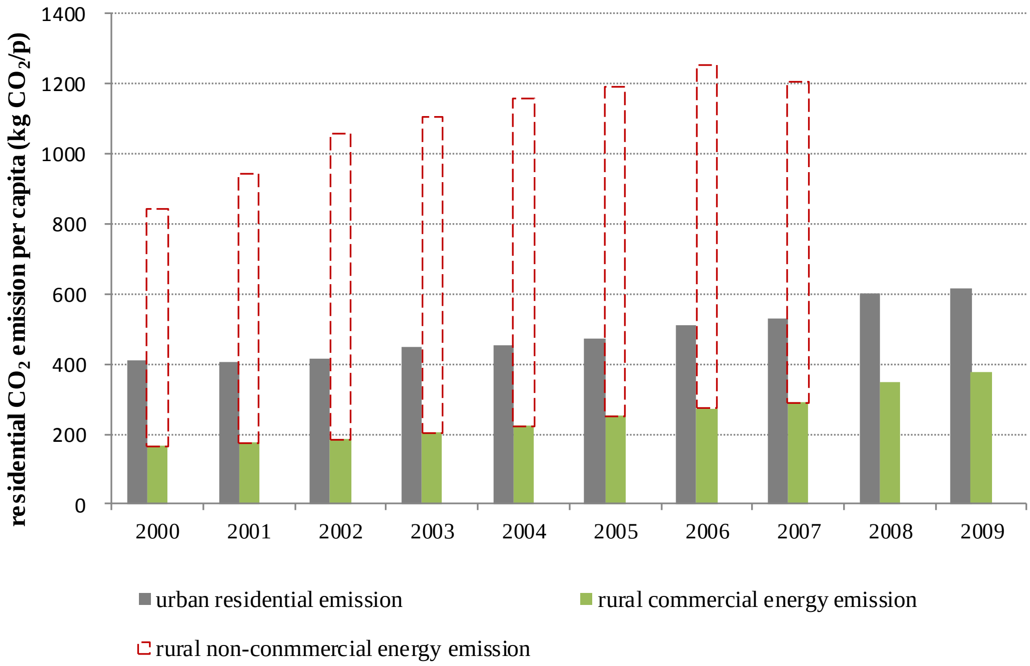

Figure 2.3 Rural and urban residential CO_2 emission per capita (kg CO_2/p)
(calculated based on data from China Energy Statistical Yearbook (2001-2010))

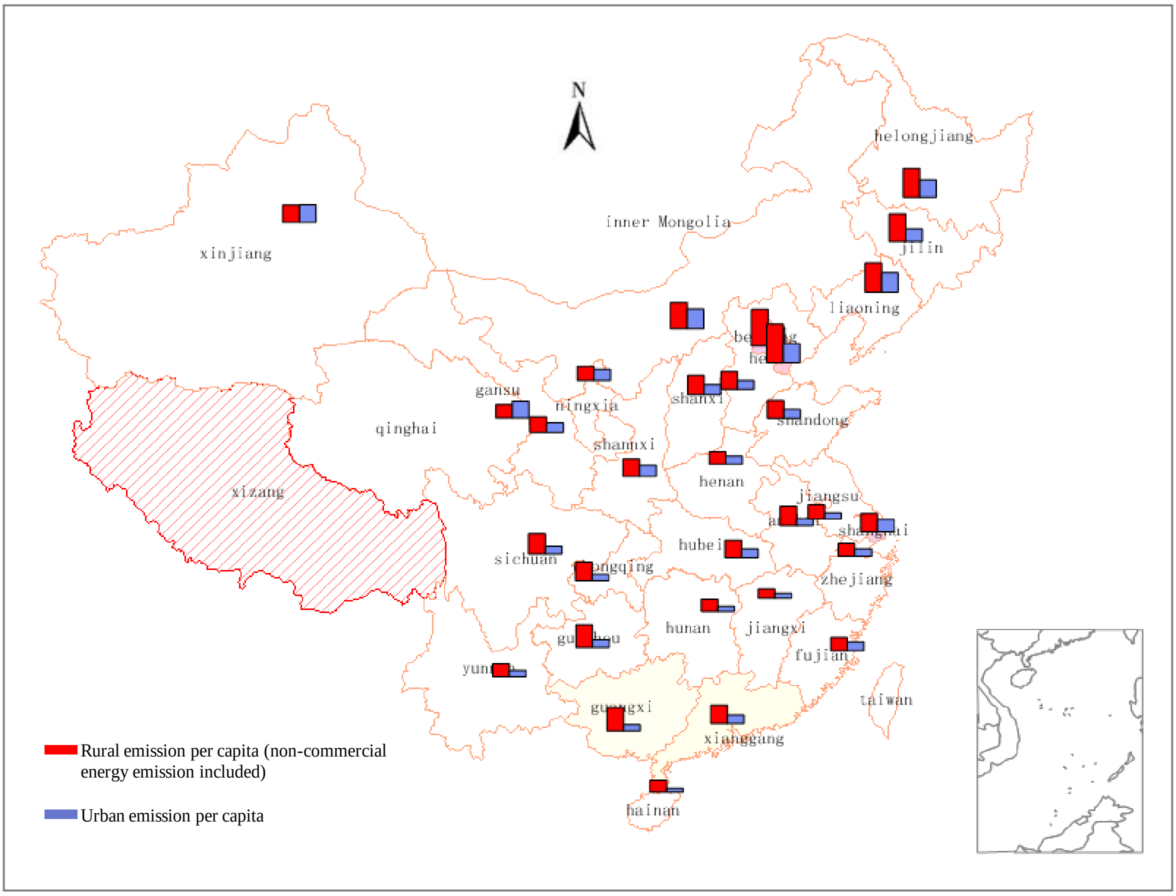

Figure 2.4 Provincial rural and urban residential CO_2 emission per capita in mainland China in 2007
(calculated based on data from China Energy Statistical Yearbook 2008)

Aside from comparing rural and urban emissions per capita, it is also important to discuss difference in emissions by province. Figure 2.4 shows a comparison between urban and rural emission per capita in each province in mainland China. A number of conclusions can be drawn. First, per capita emissions in the Northern provinces, especially in the northeast, are much higher than those of southern areas. This is mainly caused by the extra energy used for space heating in winter in the cold northern regions. Second, when emissions from traditional biomass combustion are included, rural per capita emissions are higher than urban ones in all provinces except for Qinghai and Xinjiang. In these two areas (one province and one autonomous region), urban per capita emissions are slightly higher than rural ones probably because their primitive economic conditions restrict residential energy use of poor rural residents. Third, a particularly large gap between rural and urban per capita emissions can be identified in the northeast (e.g. Heilongjiang, Jilin, Liaoning) and southwest (e.g. Sichuan, Chongqing, Guizhou, Guangxi) provinces, as well as in large metropolises such as Beijing and Tianjin. This is primarily due to the fact that massive traditional biomass energy has been used in the northeast and southwest rural areas, leading to relatively higher rural emission per capita. In large metropolises like Beijing and Tianjin, rich economic conditions allow rural populations to pursue a higher energy consumption level, while the unchanged lower efficiency of rural energy use enlarges the gap between rural and urban per capita emissions. In rural Beijing, more commercial energy is used, while more non-commercial energy is consumed in rural Tianjin.

2.4.2. Internal structure of rural emissions

The large contribution of rural residential emissions to the total CO_2 emissions in China is unexpected, as climate mitigation policies and discussions in China have been focused on reducing urban emissions and building low carbon cities. Hence, rural emission mitigation deserves more attention in addressing climate change. To achieve this, we need more information about the internal structure of rural emissions at national level and in different parts of the country. Figure 2.5 compares the contributions of commercial energy and non-commercial energy to rural residential carbon emissions in 2007. In most provinces, carbon emissions from non-commercial energy accounted for a larger proportion than commercial energy. The exceptions are metropolises such as Beijing and Shanghai, where rural residents are relatively rich and well connected to commercial energy sources compared to rural dwellers of other places. The percentage of non-commercial energy emissions was especially high in the northeast and southwest areas, where straw and firewood are widely used as fuels for heating and cooking. For instance, in Heilongjiang the percentage of non-commercial energy CO_2 emissions was 89.2%, in Jilin 80.5%, in Guangxi 91.5% and in Sichuan 82.6%. Figure 2.6 further specifies the sources of rural residential carbon emissions in 2007 for all provinces. Straw was mainly used in the northern areas while firewood was mainly used in the southern areas. Emissions from straw combustion were up to 75.4% in Heilongjiang, 63% in Jilin and 57.2% in Shandong province. On the contrary, in the southern provinces the percentage of firewood emissions was higher, with 54.8% in Guizhou, 53.6% in Yunnan and 44.3% in Hunan province. Massive firewood use poses threats to the forest and contributes to climate change.

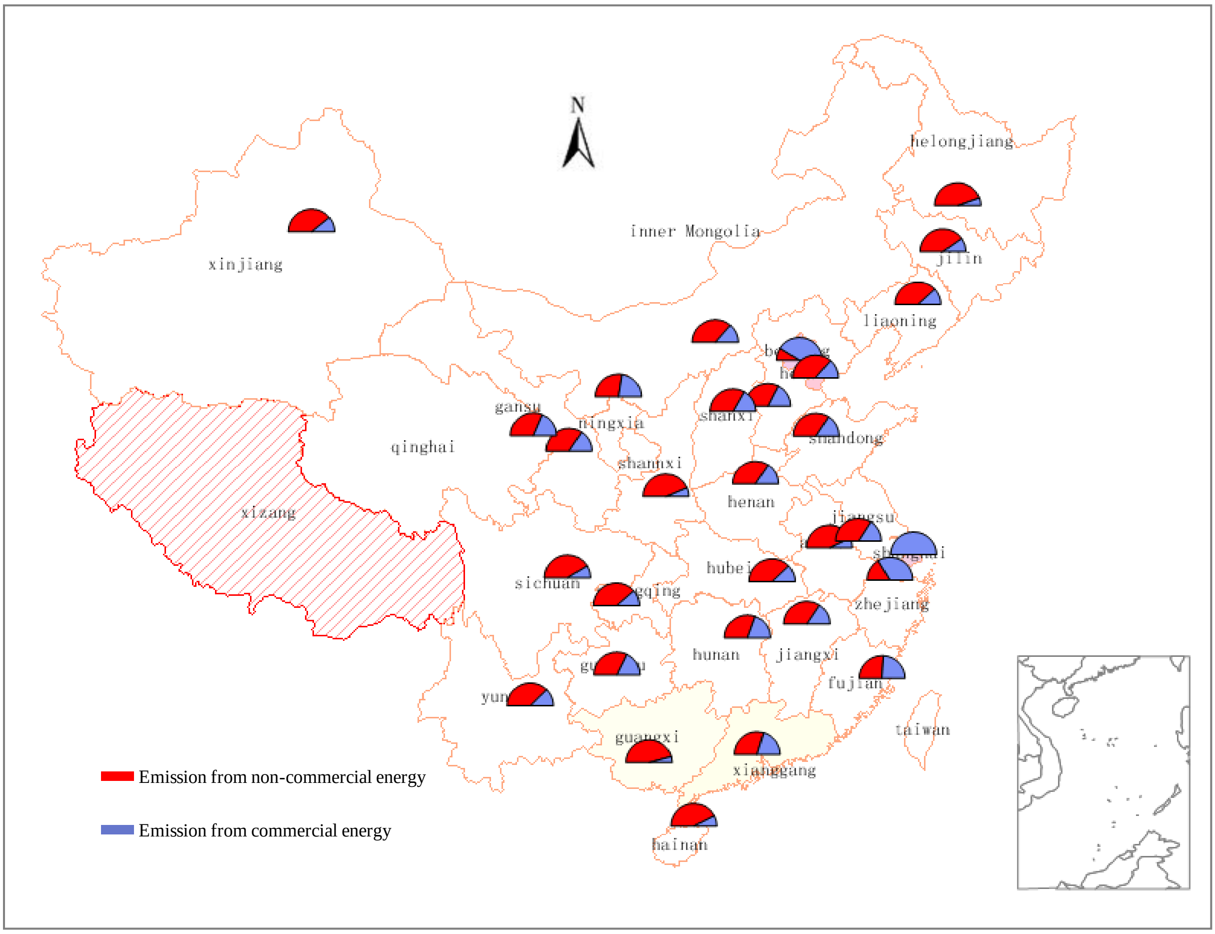

Figure 2.5 Total rural residential CO_2 emissions from commercial and non-commercial energy sources in each province of mainland China for 2007
(calculated based on Table 2.4 and data from China Energy Statistical Yearbook 2008)

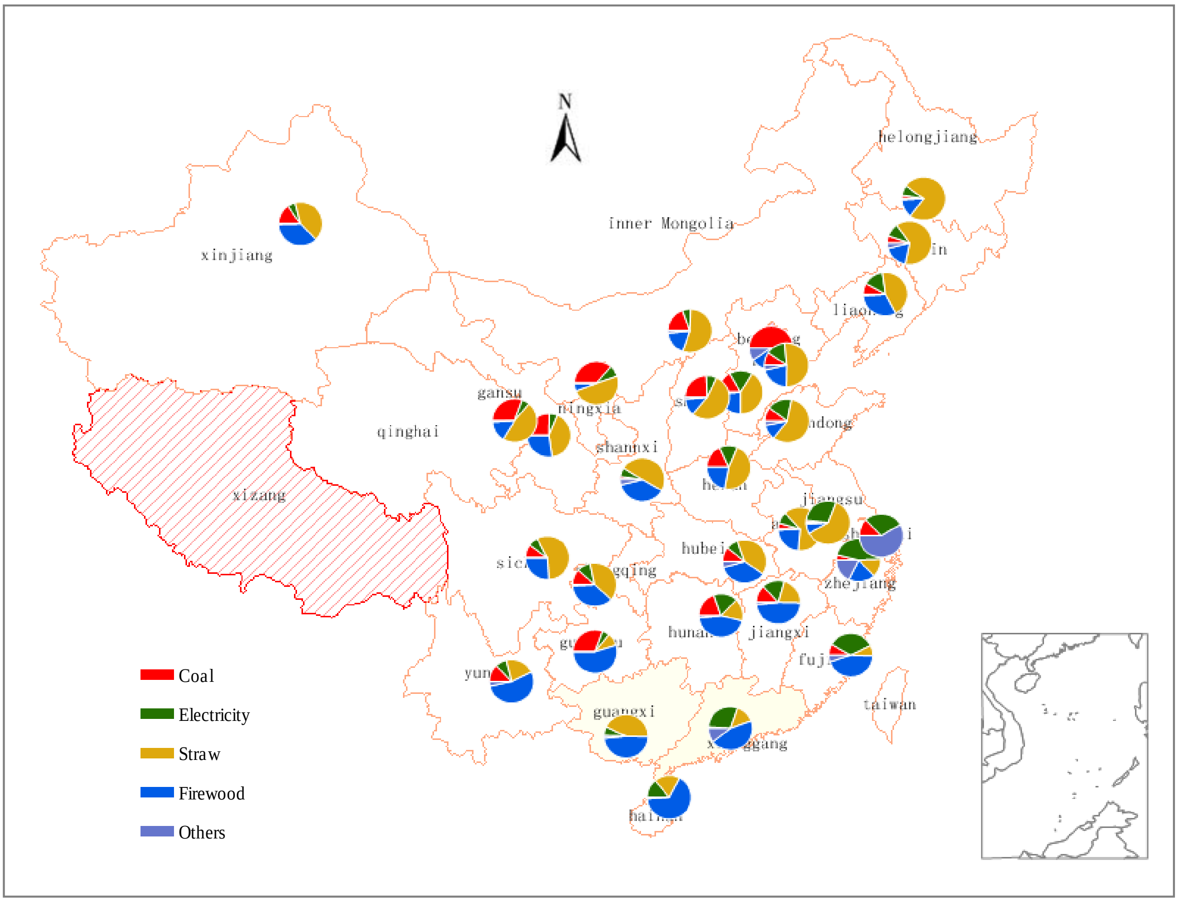

Figure 2.6 The major sources of rural residential CO_2 emissions in each province of mainland China in 2007
(calculated based on Table 2.4 and data from China Energy Statistical Yearbook 2008)

The proportion of commercial energy emissions was relatively high in the Eastern coastal areas and the northwest areas, due to major shares of electricity and coal consumption (Figure 2.6). Electricity emissions were much higher in eastern coastal provinces. For instance, electricity emissions accounted for 45.6% in Zhejiang, 34.7% in Fujian, 29.2% in Guangdong and 28.9% in Shanghai. Coal emissions were larger in provinces with abundant coal resources, mainly in northwest regions. For example, in Shanxi coal emissions contributed 24.4% to residential CO_2 emissions and in Ningxia, Qinghai and Inner Mongolia 36%, 30.7% and 19.3%, respectively. Also in the rural areas of metropolises like Beijing and Shanghai, coal and electricity were major emission sources; coal emission accounted for 47% in Beijing and no non-commercial energy was used in Shanghai.

This provincial analysis of residential CO_2 emission sources shows regional differences because of diverse geographic conditions, resource endowments, and economic bases. Based on these regional features, two conclusions can be drawn with respect to rural residential energy use.

First, the options of commercial energy sources highly depend on local economic conditions. Generally, more affluent areas have higher dependencies on commercial energy such as coal and electricity. Provinces with larger shares of commercial energy emissions also have higher per capita GDP: in 2007 Shanghai, Beijing, Zhejiang and Jiangsu rank first, second, fourth and fifth in GDP per capita, respectively.

Second, the utilization of traditional energy sources relies largely on local resource endowments (straw and firewood were widely used in provinces where they were sufficiently available). The forest coverage as well as per capita agriculture land ownership are important determining factors. For the farmers, agricultural residue is free and firewood in some cases is also directly collected by rural residents. Thus the low income of some rural residents is the main reason behind their reliance on traditional biomass use. However, to some extent this goes beyond mere economic possibilities. Foley (1995) and other concluded that farmers accustomed to using local resources sometimes have a strong preference for biomass energy even when other energy options are physically and economically available. This behaviour, which depends on using traditional energy sources, makes shifting to other energy sources in rural areas difficult.

2.5. Policy options

Carbon emissions from traditional biomass combustion contribute to more than half of the total rural residential emissions. Aside from its contribution to global warming and deforestation, the current biomass combustion also contributes to hazardous substances emissions that pose threats to human health and the rural environment. This makes it imperative to introduce policies to reduce emissions from traditional biomass energy use among rural residents, though these policies have not been a priority during the past several decades. A number of policy options can be part of such a policy agenda.

One important initiative is promoting the transition of rural residents' energy options toward more commercial energy use and reducing their dependence on traditional biomass use. While rural agricultural production and rural industrial production have stimulated the switch towards commercial energy use in recent decades, rural residential energy use seems to continue to lag behind. The local availability and use of fossil fuels such as LPG, oil, and electricity (based on fossil fuels or renewables such as wind or hydro) can be incentivized through policies and programmes.

Second, policies towards the further stimulation of decentralized renewables--such as solar water heater, micro hydro installations, household biogas installations, PV (Photovoltaic) panels or solar cockers--can significantly reduce CO_2 emissions, but do not directly imply a transition towards commercialized energy. Various programs already exist but not all have been implemented successfully on a large scale, and certainly not in rural areas. Solar water heaters for instance, have been installed widely in China, but are much more common in urban areas than in rural areas (Han et al., 2010). Hence, targeted programs for decentralized rural energy production and use need to be given priority.

A third policy option is to shift current traditional biomass energy production to forms that use biomass more efficiently and produce less CO_2 emissions per unit of biomass. Given the fact that large biomass resources are and will continue to be available for energy production in China (cf. Han et al., 2008), more efficient forms of biomass-based energy production are required. Centralized biomass power generation, biomass briquettes, and biogas production from wastes could be further deployed and popularized. Current policies have established a series of strategic targets and measures in terms of biomass utilization, with added funding and subsidy schemes (e.g. on household biogas production and use; MOA, 2007). This resulted in the increase of small-scale household biogas installations from around 8 million at the turn of the Millennium to around 40 million in 2010. But further policies and measures are needed to improve maintenance, efficiency and the replacement of traditional biomass use.

Finally, taking into account rural residents' preference for conventional biomass use, it is important to improve combustion efficiency of household appliances (such as stoves) that use traditional biomass. MacCarty et al (2008) show that improved combustion methods of biomass cooking stoves potentially reduce global warming effects (CO_2 emissions) by 40-60%. Nowadays, out of the 250 million Chinese rural households, 110 million households still use traditional stoves. If these stoves were replaced by energy-saving stoves, heat efficiency would improve by approximately 10% - 30% with 138 million tons of CO_2 reduction[11].

In order to implement these policies, they must be tailored to various situations within each province, in addition to having a national policy and legal framework. Hence, multi-level

[11] Sources: 2010 China Biomass Summit. http://www.022net.com/2010/6-2/445524122743084.html

governance arrangements have to be designed that include local stakeholders and even end-users to fine tune policies and measures to local situations and energy use practices.

2.6. Conclusion

This paper provided an overview of rural residential energy consumption and estimated its CO_2 emissions. In most greenhouse gas emission calculations, biomass carbon emissions are not accounted for and are often considered carbon neutral. In contrast, we included traditional biomass use in carbon emission calculations in order to find out the major sources of rural residential carbon emissions. This clarified climate change mitigation potential and provided focal points for energy and climate change policies.

We did not find the same transition of residential end-use energy structure as described by Zhang et al (2009$_a$), a steady decrease in the proportion of biomass use and increase in the percentage of coal and electricity use. In terms of energy use for livelihood, the amount of commercial energy use is indeed rising annually, but consumption of non-commercial energy sources did not show an obvious decrease. Previous studies have focused on rural energy used for both livelihood and production, and the structural change towards increased commercial energy use was found especially true for rural production (including agricultural production and rural industrial production). Residential rural energy use has been undergoing a much slower transition to commercial energy.

Hence, to tackle climate change and energy issues in rural China, residential rural energy utilization should be given much more attention. More and more efficient commercial energy use for residents should be strongly included in future rural energy development programs. Following programs and policies such as “home appliance going rural” and “motorbike going rural”, China is in need of programs and policies such as “commercial energy going into rural areas.” But this is certainly not the only policy option that can be followed in order to reduce CO_2 emissions from rural residential energy use. Alternative decentralized energy production, more centralized and efficient biomass use, and increased efficiency of household appliances that use traditional biomass have also significant potential.

There are major differences between provinces, both in the contribution of traditional biomass use (such as firewood and straw) to GHG emissions, and in the potential to reduce that contribution. Resource endowments and economic development are the primary determining factors of these differences. Hence, energy policies need to be location specific. Policy support for more primitive and poverty-stricken areas needs to combine increasing energy input with enhanced energy management. Such policies have to take both energy consumption and energy provisioning into account, as it is at this crossroad that both levels of CO_2 emissions are determined.

In the end, as pointed out in the beginning, incomplete data and inconsistencies among data from different sources is a source of uncertainty in this kind of study. Not only for research, improving data collection and the quality of statistics of rural energy use is definitely necessary and important for policy making and implementation.

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Chapter 3. Rural public acceptance of renewable energy deployment: the case of Shandong in China[12]

Abstract

China has set ambitious goals to increase the use of renewable energy. Developing renewables in rural areas is also one of the most important energy strategies. This paper examines rural social acceptance of renewable energy deployment taking Shandong as a case study via a field questionnaire survey. Theory of planned behaviour is adopted to establish an analytical framework, and a logit model is used to examine possible determinants of local social acceptance. The results show that rural residents are generally supportive renewable energy development given its positive impacts on environment. A stated willingness to pay more for renewable electricity is taken as a variable representing an individual's behavioural intention. The probability of occurrence of positive intention is found to increase with household income, individual knowledge level and belief about costs of renewable energy use but decrease with individual age. Residents with higher level of income are more likely to be willing to pay more for green electricity, so are the younger people. Enhancive knowledge and understanding about renewable energy (for instance, the cost) would be conducive to win public acceptance of renewable energy deployment.

Key words:

Local acceptance, renewable energy, willingness to pay, rural, China

3.1. Introduction

Development of renewable energy resources is being promoted as a promising method of solving rural energy issues and improving life condition of rural dwellers. As planned in the mid and long term development plan of renewable energies in China, up to 70% of rural households should have adopted renewable energy in their daily lives by 2020 (NDRC, 2007).

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Although governments and research institutes worldwide express a generally positive attitude towards renewable energy, these years have witnessed that some renewable energy projects faced resistance from the local population (Upreti and Horst, 2004; Kaldellis, 2005). Some studies also demonstrated the contradiction between an ambitious high-level target and weak local acceptance (Batley et al., 2001). It is especially common in China that a target is set via top-down approaches, but in terms of public preferences less are concerned with.

Rural dwellers are major consumers of energy for rural residential use. However, their preferences are easily overlooked given their little involvement in decision-making of public projects. Actually rural households could be easily involved in the production of (renewable) energy. The production of renewable energy by Chinese rural households plays a key role in the formation or transformation of rural domestic energy uses. So far rural renewable energy utilization is mainly in the field of residential use (CCICED, 2009), and is mainly in the forms of biogas and solar energy utilization operated by households themselves. Learning the attitudes of rural residents towards renewable energy, we are better able to understand how to expand renewable energy in rural areas as a way of reducing carbon emission and improving rural living conditions.

Previous literatures pay a lot of attentions on public acceptance of renewable energy, however mainly developed countries are studied which have made a good progress in the development of renewable energy. Surveys generally proved moderate to strong overall public support for renewable power such as wind power (Krohn and Damborg, 1999), while there also appear some examples of such projects failure associated with low local acceptances or public opposition (e.g. Upreti and Horst, 2004; Kaldellis, 2005; Wüstenhagen et al., 2007). For instance, it was found of considerable oppositions from the public to the development of biomass energy in the UK, and strong resistances to wind energy application in the Greek mainland and in Germany. Studies on social acceptance of renewable energy development vary from large scale grid connected power generation to small scale stand-alone projects. Aimed at either supportive public attitudes or local resistances, potential affecting factors and their influences are examined by many scholars (e.g. Kaldellis, 2005; Hansen et al., 2003; Joberta et al., 2007). Among these studies, some would mainly look at institutional capacity behind consumers' acceptance with a contextual point of view, for example, those physical characteristics, economic incentives, regulations and cooperation mechanisms are referred as major determinants (Molnarova et al., 2012; Wolsink, 2000; Sauter and Watson, 2007). Differently, other studies would focus on individual intention and behaviour with a view of social-psychological view (Huijts et al., 2012) such as environmental activism, and quantitative analysis was widely applied for these studies (Bang et al., 2000; Tanner and Kast, 2003; Hansla et al., 2008; Hevine-Wright, 2011). Willingness to pay for renewable energy was usually evaluated as a reflection of residents' attitudes or preferences (Nomura and Akai, 2004; Zografakis et al., 2010), followed by some examinations on determinants or influencing factors of social acceptance. For instance, Hansla et al (2008) indicated that willingness to pay for green electricity increased with a positive attitude towards green electricity that related to awareness of consequences of environmental problems and decreased with electricity costs, similar with the results proved by Bang et al (2000) using reasoned action theory. Site-specific or personal factors are pointed out to be with major influences (Joberta et al., 2007) which may refer to socioeconomic characteristics, living conditions (Tanner and Kast, 2003), family income, residence size (Zografakis et al., 2010), individual age, education (Ek, 2005), social status (Batley et al., 2001) and personal experience (Batley et al., 2000) and so on.

In general, previous studies focused on countries where there have been exact reduction targets or policy goals with respect to greenhouse gas mitigation. Especially, the gap between national target that increases the share of renewable energy and social acceptance was discussed by some researchers, who stated that social acceptance may be a constraining factor in achieving ambitious government target (Batley et al., 2001; Wüstenhagen et al., 2007). This indicates the great importance of social acceptance in the development of renewable energy. There is also some research aimed at local acceptance or preferences in terms of diffusion of new technology or new policy in China. For example, determinants of public acceptance are examined in Wang et al (2012) by looking at tiered electricity reform in China with case studies from four urban cities; determinants of urban household electricity-saving behaviour are discussed by Wang et al (2011) from the aspects of economic benefits and social norms, etc.; Zhang et al (2011) analyzed public acceptance of electric vehicle in Nanjing of China and its affecting factors; Yuan et al (2011) investigated the social acceptance of solar energy technologies from end users' perspective in Shandong province which showed a considerable high level of social acceptance and public awareness of solar water heater. In general, developing renewable energy in rural areas is at an initial phase; in contrast to emphasis placed upon ambitious national targets, little understanding has been obtained or studied concerning rural residents' opinions. The objective of this study is to examine general local acceptance of renewable energy in rural areas of China as well as residents' preferences for energy provision, and to find out potential influencing factors which are probably helpful to win public support. While at present despite of established national targets, there are quite limited exact targets or planning in local rural regions. Before this research, we conducted a pre-test field survey which showed rural people only understand renewable energy generally as a kind of environment friendly sources. In light of their limited knowledge about renewable energy, currently it is difficult to evaluate rural residents' acceptance aimed at distinguished renewable technologies. Hence what we intend to focus on in this paper is the common character of kinds of renewable energy sources, that is they would have positive impacts on environment, but perhaps need higher cost input compared with traditional fossil fuels. Given this common character of renewable energy sources, we tried to examine the attitude of rural dwellers towards it and their willingness to pay for the 'higher cost'.

This paper proceeds as follows. Section two briefly introduces a background of renewable energy development in rural China, followed by a theoretical framework and elaborated methods in section three. Section four presents the main findings of the survey and econometric research. The conclusion and some implications are discussed in section five.

3.2. Renewable energy and electricity price in rural areas of China

Recent years have seen a rapid deployment of certain renewable energy within rural areas of China, which is closely tied to the country's rich experiences in developing for instance biogas, and the strong support of state funds (e.g. subsidies for biogas and solar water heater) (Chen et al., 2010). As listed in Table 2.1 in Chapter 2, rural biogas output increased from 2.59 billion m^3 in 2000 to 11.8 billion m^3 in 2008. Besides, solar energy is being widely adopted, the area of solar water heater installation increased from 11 million m^2 in 2000 to 47.6 million m^2 in 2008; the solar cookers installed increased three fold from 2000 to 2008. However, we should keep in mind patterns of renewable energy utilization in rural areas are quite limited, and meanwhile the substitution effect acting on the reduction of conventional energy use is not so obvious. For instance, the use of solar water heater could provide more comfortable and convenient living environment to rural households, while it hardly substitutes traditional energy use for hot water, since before the use of solar water heater rural residents mostly may accept a lower life quality.

Despite the wider use of certain renewable energy sources, it also appeared some unsuccessful examples. In a survey conducted by Han et al (2008) in the same Shandong province, it was found four out of seven biogas stations had been out of use within ten years. Institutional, technical and financial shortcomings were examined, in particular, a lack of public support was found to be an important cause of the project failure. For instance, villagers were unwilling to change cooking routines and refused to pay for the installation of pipes and stove for biogas use, and even some villagers refused to pay for biogas. Obviously, there are various obstacles to renewable energy deployment especially in rural areas in light of poor economic condition, low educational level and others. It needs to explore pathways suitable for rural China focusing on participation mechanism or policy systems including price management and subsidy system.

Different from many developed countries, where households need to pay more if they choose and consume green electricity rather than traditional thermal power, so far in China the higher cost of electricity production from renewable energy is to a large extent balanced by governmental subsidies. For instance, for electricity from biomass power generation a subsidy of 0.25 Yuan per kWh is provided. Now the price of electricity in the survey area is 0.5469 Yuan[13] per kWh (both urban and rural). In some other provinces there exist different prices for urban and rural residential electricity use, where rural electricity is more expensive since it needs to cover maintenance fee for rural low voltage grid. Residents purchase electricity from the power grid with the price referred above but they cannot choose or in the other word have no idea what kinds of electricity they use (renewable or traditional). Regarding renewable energy generation, grid enterprises could collect power price additional from electricity consumers in the service scope of provincial (and above) power grid enterprises, while consumers in the service scope of prefecture and county level power grids (rural residents) are no extra charged at the time being, neither is the electricity consumption for agricultural production. However, judging from experiences of countries with remarkable renewable energy development, high price of green electricity is bound to be spread upon end-use consumers and a diffusion of green electricity surely needs to rely on consumers' choices and behaviours. That may also be a future in China.

[13] Data source: the field survey

3.3. Methodology

3.3.1. Theoretical framework

As reviewed regarding local acceptance or support for renewable energy, there have been ample studies focusing on its diverse dimensions. Different from those with a contextual point of view, in this study we will focus on a perspective of individual behaviour (intention), with stated behavioural willingness taken as a variable testing local acceptance. The reasoned and planned action theory was adopted to constitute a theoretical framework.

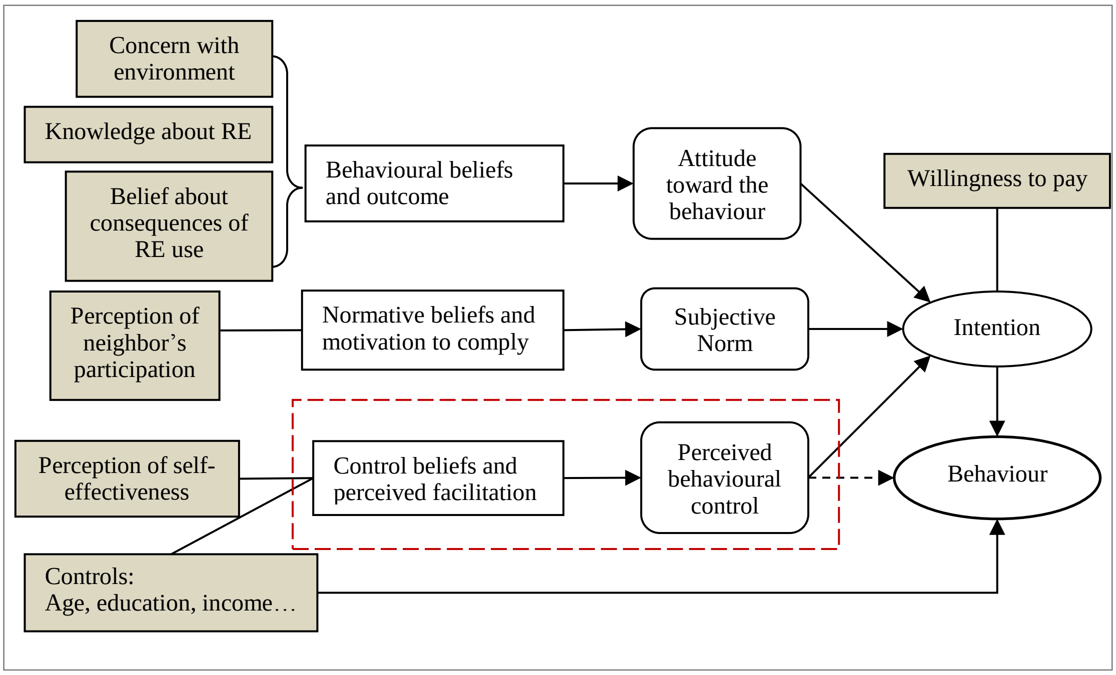

Figure 3.1 An analytical framework based on the theory of planned behaviour (Adopted from Ajzen (1991), pp.182)

The theory of reasoned action was founded by Fishbein and Ajezen (1975). Based on the proposition that an individual's behaviour is determined by the individual's behavioural intention, it suggests that people consider the consequences of behaviours before engaging in them, and that they choose to perform behaviours that may lead to desirable outcomes. In line with this theory, behavioural intention is derived from two aspects of factors: attitudes towards the specific behaviour and subjective norms. Attitude toward the behaviour is defined as "a person's general feeling of favorableness or unfavorableness for that behaviour" (Ajzen and Fishbein, 1980). The formation of an individual's attitude can be explained by the individual's salient beliefs and outcome evaluations associated with that behaviour. The subjective norm is the sum of the product of the belief that relevant other salient individuals or groups think the individual should comply with the behaviour and the motivation to comply with relevant others (Bang et al., 2000). The theory of reasoned action was more based on voluntary behaviours stemmed from personal attitudes and subjective norms at the beginning. While the behaviour is not completely voluntary but always under some control, to deal with this problem, Ajzen (1985) extended the theory of reasoned action by including another construct, perceived behaviour control, as depicted in Figure 3.1. The extended model is the theory of planned behaviour. Perceived behavioural control refers to "people's perception of the ease or difficulty of performing the behaviour of interest" (Ajzen, 1991). It is explained as a function of control beliefs and perceived facilitation. Control belief is the perception of the presence or absence of requisite resources (e.g. personal capacity, required information) and opportunities needed to carry out the behaviour. Perceived facilitation is one's assessment of the importance of those resources to the achievement of outcomes (Ajzen and Madden, 1986).

The theory of reasoned action (or the theory of planned behaviour) has been successfully applied to a large number of situations in explaining or predicting the performance of behaviour and intentions (e.g. Chang, 1998; Hansen et al., 2004). Based on this theoretical framework, we attempts to evaluate residents' attitudes toward and preferences for renewable energy (RE), however, following Bang et al (2000), not actual behaviour is tested or predicted but their intention to engage in the behaviour of paying extra monies to consume renewable energy (willingness to pay) is evaluated. We also examine relationships between variables to find out potential factors that affect respondents' behavioural intentions. An analytical framework in this study is developed as depicted in Figure 3.1. The key variables measured associated with attitude toward behaviour are concern for environmental problems, knowledge about renewable energy and beliefs about consequences of renewable energy use (benefits and extra costs); perception of neighbors' participation is added as a representative of the subjective norm; perception of self-effectiveness (Liu et al., 2010) and the demographic characteristics of the respondents, such as age, gender, education and income, are defined as control variables that partly reflect perceived behavioural control. How to measure these variables will be explained in the next section.

3.3.2. Outline of the questionnaire and evaluation of variables

The questionnaire (see Appendix I the questionnaire) is designed based on the analytical framework shown in Figure 3.1. Different questions are set to evaluate various variables. We try to examine the respondents' concern with environment, knowledge and beliefs by asking their understandings of relative topics. As shown in Table 3.1, a few questions are asked aimed at each variable and accordingly different options (answers) are given certain values. Specifically, to test the individual's knowledge about renewable energy, we set two questions: for the first one, who answered rightly about the understanding of renewable energy would get one score and wrong answer scored '-1', 'no idea' scored '0'; the second question listed seven types of renewable energy utilization and score is given according to how many types are selected by the respondent, which means who identified one type would get '1', and two types get '2' by such analogy. With respect to concern with environment, kinds of rural environmental problems and one choice stating 'no concern' are listed; however, an individual could be concerned with the environment and not necessarily identify with all the problems listed, we did not evaluate the degree of individual's concern with environment, but set this variable as a dummy variable assigned with the value '0' (without concern) and '1' (with concern). To test the respondents' beliefs about benefits or costs of utilization of renewable energy, respectively five and three relative statements were provided as shown in Table 3.1, a value '1' is given to the item if the answer is 'agree' , '-1' is given if the answer is 'disagree', and '0' is given to 'no idea or neutral' answer. Then an aggregation of values obtained from the evaluation of all associated questions or statements is taken as the estimated value of this variable, and the Table 3.1 also gives the value scope of each variable. Before input into the logit model (in section 3.4.2) each variable is standardized to make them comparable.

Table 3.1 The methods used for valuation of the main variables

Variable	Original value scope	Questions/statements	Valuation: -1	0	1	2	3	4	5	6	7
Concern with environment	0 or 1	Are you worried about the following rural environmental problems?		Not at all	Either problem is selected						
Knowledge about renewable energy	-1~8	How do you think about renewable energy	High pollution	No idea	Kind of clean energy						
		How many options do you think are		None	One	two	three	four	five	six	seven

		renewable energy use?			
Belief about benefits from Renewable energy use	-5~5	It would improve public surroundings in rural areas	Disagree	No idea or neutral	Agree
		It would improve energy supply of rural areas	Disagree	No idea or neutral	Agree
		It would improve indoor environment, and comfort level of households	Disagree	No idea or neutral	Agree
		It can protect forest and mitigate greenhouse gas emission	Disagree	No idea or neutral	Agree
		Increasing renewable energy production could create more employment	Disagree	No idea or neutral	Agree
Belief about costs of renewable energy use	-3~3	It also may lead to some negative effects, like noise during wind power construction	Disagree	No idea or neutral	Agree
		High investment demanded by renewable energy utilization would bring higher electricity price	Disagree	No idea or neutral	Agree
		Instability during renewable energy generation would cause much pressure for the grid	Disagree	No idea or neutral	Agree

Evaluation of other variables was also based on specific and targeted questions. To test ‘the perception of neighbor’s participation’, the possibility of being influenced by neighbors if they start to use biogas or solar energy was asked; with the answer of ‘being possible’ or ‘being impossible’, the value ‘1’ or ‘0’ is given to this variable. For ‘the perception of self-effectiveness’, question ‘*if you begin to use more environment friendly energy, do you think you will be appreciated within the society and probably influence others*?’ was used; similarly, the value of this variable may be ‘1’ if ‘yes’ is answered and ‘0’ otherwise. Besides these, other personal control variables are also examined in the questionnaire including individual age, gender, education and income level.

Respondents’ attitudes were directly asked towards renewable energy deployment and rural energy transition. Their ‘willingness to pay’ was inquired as ‘i*f you are willing to pay more* *for renewable electricity, imagine that your yearly electricity bill 1000 Yuan, how much extra would you be willing to pay to get all of your electricity from renewable sources?*', a few options such as '10%-20% more' were provided.

3.3.3. Study area and samples

We conducted a questionnaire survey in April, 2011 in Zhangqiu County of Shandong province. Shandong has almost 90mn inhabitants and the third largest GDP in China. As an agricultural province, the output of agricultural sector ranks first in the country, correspondingly rural inhabitants account for more than 62% of the provincial population. Rural poverty and complex rural energy issues have become big challenges in the trend of low carbon development. Shandong province shows typical characteristics of China in terms of economic and energy structure, for instance, it has a similar industrial structure with average national level. Being rich in biomass resources, Shandong has taken utilizing renewable biomass energy as an important energy strategy of the province. Solar energy and wind power are also emphasized in the energy strategy. Rural areas will be a major domain where these renewables should be developed and will play more important roles in the transition of energy structure.

Figure 3.2 The location of the survey area.

Zhangqiu is a county-level city governed by Jinan city, located by the Yellow River. Figure 3.2 shows the location of the survey area. This county-level city has a land area of 1855 km^2 and a population of around one million, governing 908 administrative villages. In 2010, the urban per capita disposable income in Zhangqiu was 16,906 Yuan (11.5% lower than the national average), and rural per capita net income was 10,138 Yuan which was 1.71 times the national average (all in Chinese currency). It also had made some achievements in terms of renewable energy utilization in this area, where there have been more than 24,000 household biogas installations and around 5000 solar water heater installed up to 2010[14]. We suppose the relatively rich background in rural economy may indicate relatively high educational level of local residents, and also consider their experiences in utilizing biogas and solar energy, both of which would to some extent facilitate the communication with local residents for the research.

Three villages called Yanghu, Tengpeng and Baozhuang were selected to carry out the questionnaire survey. They are located very closely with similar living background. In each village around 70 residents were randomly selected as the interviewees. In light of a relatively low education level of rural residents, the survey was conducted by direct interviews of the target respondents with each question given detailed explanations by interviewers. A total of 212 valid responses were successfully obtained. The distribution of demographic characteristics of respondents is listed in Table 3.2. Around 60% of the respondents have received junior or senior middle school educations, and an additional 15% had a college education. Also about 40% of them report an individual annual income more than 10,000 Yuan (the regional average is 9190 Yuan). The gender, age and household income of the respondents are almost evenly distributed.

Table 3.2 A descriptive statistics on the samples

Variables	Options	Count	Percentage (%)
Gender	Male	96	45.3
	Female	116	54.7
Age	<18	1	0.5
	18-30	33	15.6
	31-40	58	27.4
	41-50	43	20.3
	51-60	34	16.0

[14] The national economy and social development statistical bulletin of Zhangqiu in 2010. Available at: http://www.zhangqiu.gov.cn/tabid/713/InfoID/18894/frtid/352/Default.aspx

	>60	42	19.8
Education	Illiterate	17	8.0
	Primary school	32	15.1
	Junior middle school	90	42.5
	Senior middle school	42	19.8
	College	31	14.6
	Graduate and above	0	0.0
Personal annual income (10^3 CNY)	<5	80	37.7
	5-10	47	22.2
	10-20	38	17.9
	20-30	23	10.8
	30-40	14	6.6
	>40	9	4.2
Household annual income (10^3 CNY)	<10	33	15.6
	10-20	40	18.9
	20-30	38	17.9
	30-40	42	19.8
	40-60	32	15.1
	>60	25	11.8

3.4. Results discussion

3.4.1. Knowledge, belief and attitude of consumers

With a total of 212 valid responses collected, we observed the following results:

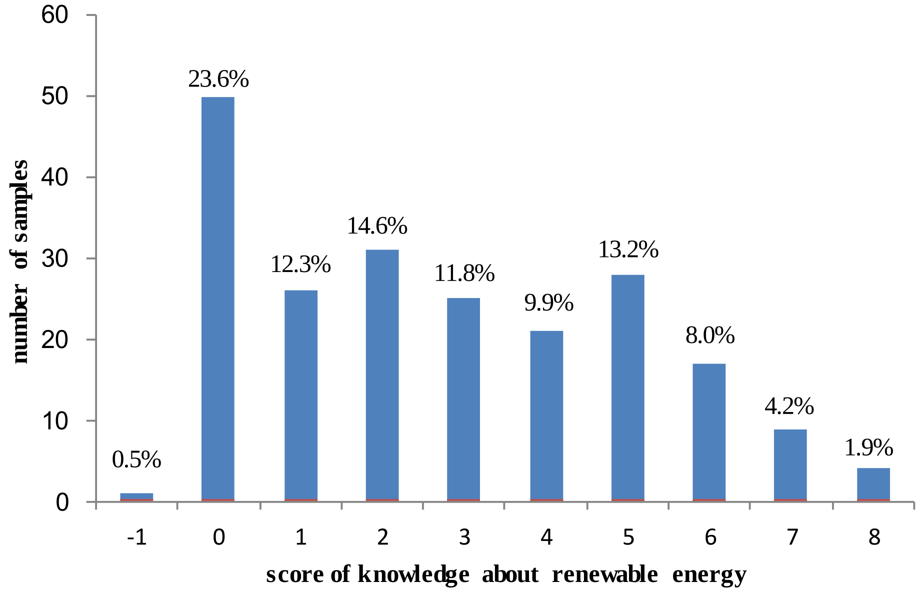

Figure 3.3 Valuation of ‘knowledge about renewable energy’

According to a valuation on variable 'concern with environment', we found most of the respondents showed concern about rural environmental problems such as shortage of commercial energy and rural water and air pollution, but 22.6% of them stated they are not concerned with rural environmental problems at all. A test on their knowledge about renewable energy did not present special distribution features. As depicted in Figure 3.3, most respondents scored from 0 to 5, only 1.9% of them scored the maximum. In general their knowledge about renewable energy was at a moderate level.

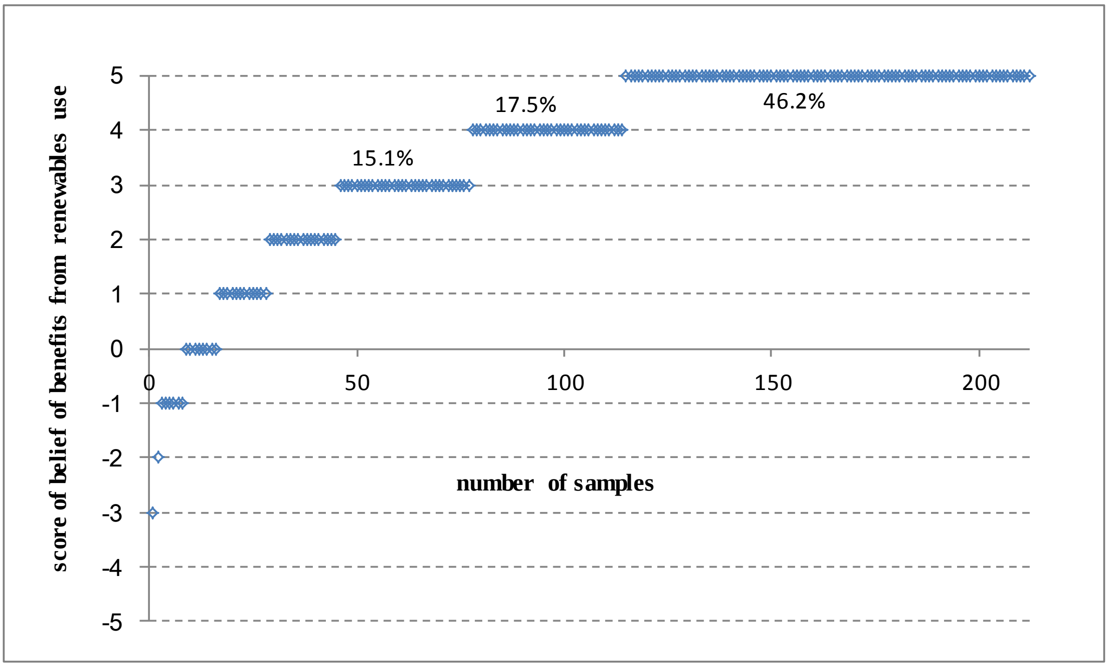

Figure 3.4 Valuation of belief about benefits from renewable use (-5~5)

We also evaluate the respondents' beliefs about the consequences of renewable energy use. Figure 3.4 shows the results of a valuation on their belief about benefits from renewable energy use such as improving rural environment and mitigating greenhouse gas emission. We can see rural residents showed a high degree of belief about the benefits from renewable energy use, 46.2% of them got the full marks and most of respondents scored 3 and above. That implies they knew very well about possible positive consequences of adoption of renewable energy. While as for the belief about extra costs caused by renewable energy utilization it presents different results. As provided in Figure 3.5, the valuation of their beliefs about extra costs presented a nearly even distribution within its scoring interval. Only 13.2% of the respondents scored the full marks, 23.1% of them stated that they had no idea about the cost, and 35.4% of them (who got negative points) did not think developing renewable energy would increase the investments or costs.

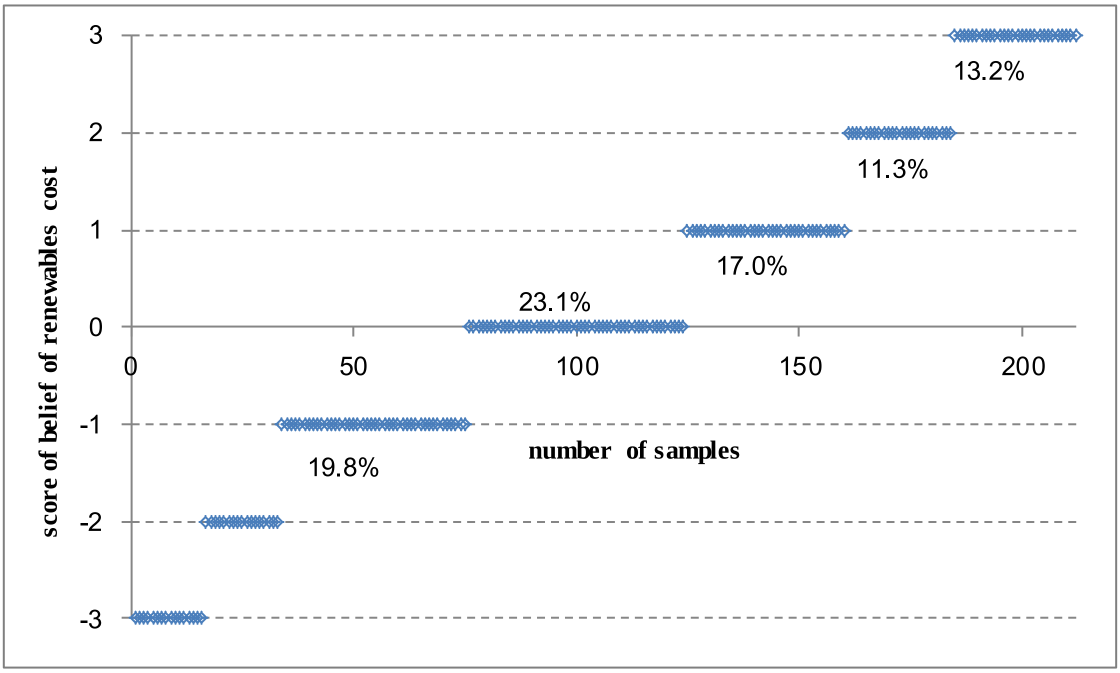

Figure 3.5 Valuation of belief about costs of renewable use (-3~3)

As designed in the theoretical framework, variables ‘perception of neighbors’ participation’ and ‘perception of self-effectiveness’ are added to examine effects of subjective norm and perceived behavioural control. The results showed neighbors’ behaviour really mattered, since 84% of the respondents stated that they are very likely to take the same action if their neighbors choose to use biogas or solar energy. This indicates rural residents are highly likely to be influenced by their neighbors’ energy options and behaviours or in other words patterns of energy use. It may be normal since in one village we often see households may share a similar lifestyle, especially in terms of daily energy use. That is because they are facing the same resource endowment and culture background, energy options may, however, vary across households with different economic conditions. In principle, such a result suggests there perhaps would be a cluster effect in rural China because households probably follow the example of each other, thus it would be quite effective to diffuse use of renewable energy if a successful case appears. The respondents also showed some confidence of the effectiveness of their personal actions, more than 90% of them believed their behaviour of using clean energy such as biogas or solar energy would be appreciated socially and probably would positively influence others.

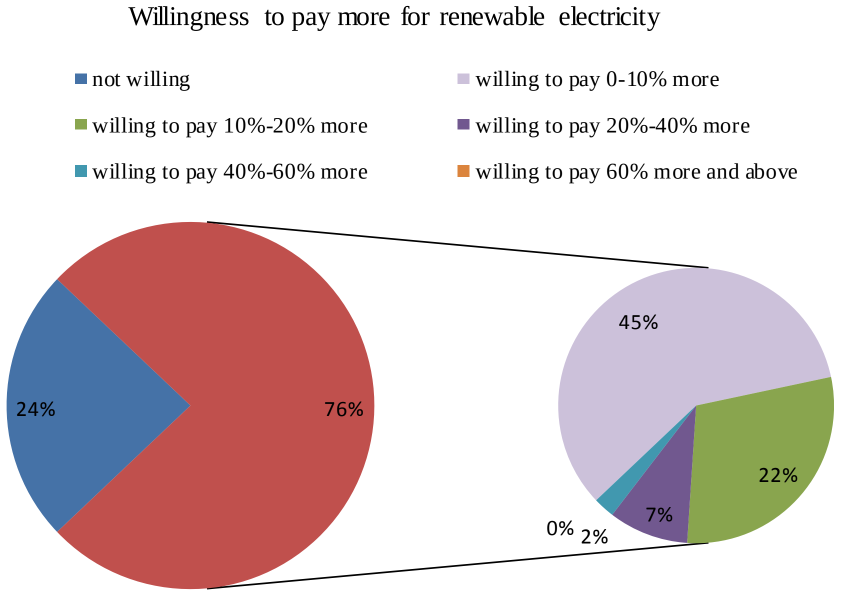

Figure 3.6 Respondents' willingness to pay more for renewable electricity

In spite of moderate level of concern and knowledge, stated attitudes of rural residents showed an extremely high degree of support for renewable energy development and rural energy transition towards environment friendly direction. When asked whether rural energy should become cleaner and more low-carbon, nearly 99% of the respondents answered 'Yes' and others expressed unconcern. Similarly, most of the respondents stated to be willing to pay extra money for renewable electricity, as shown in Figure 3.6, except 24% of them expressed unwillingness, nearly a half of them could accept a '0-10%' extra payment, but if charged more they would refuse to pay. Overall, stated willingness to pay of rural dwellers was quite high, but the extra payment should be in a limited range. In principle, it showed a high degree of public acceptance regarding renewable energy deployment in rural areas of China.

3.4.2. Determinants of 'willingness to pay'

We further investigate the main driving forces behind the stated willingness to pay of rural residents. Previous research suggests that stated a willingness to pay for renewable electricity is positively related to income, social group and education (e.g. Ek, 2005; Batley et al., 2000; Roe et al., 2001; Zarnikau, 2003). In this study, based on the theoretical framework, we try to examine whether an individual's willingness to pay is influenced by the individual's knowledge about renewable energy, concern with environment, belief about consequences of renewable energy use, and demographic characteristics such as education and income. The following binomial logit model is established as shown in the following equations:

$$P(Y = 1) = exp(z) / (1 + exp(z)) \quad (1)$$

$$z = \beta_0 + \sum_{i=1}^{n} \beta_i x_i + \varepsilon_i \quad (2)$$

Where, β is a vector of parameters to be estimated, x_i the vector of observations of explanatory variables, ε the random error term (assumed to follow a standard normal distribution). The dependent variable was set equal to one if the respondent stated positive willingness to pay more for renewable electricity, zero for the occurrence of negative willingness to pay. The model should include all variables theoretically accepted. While adopting a backward stepwise selection method we found the variable 'perception of self-effectiveness' had no significant effects on the model and was removed. Multi-collinearity was further checked among independent variables. Variance inflation factor (VIF) for all independent variables range from 1.005 to 1.197 (< 5), which means multi-collinearity should not be a serious concern in our regression. The coefficients are estimated by maximizing the likelihood function, finalized independent variables and the empirical results are listed in Table 3.3.

The model 1 estimate influences of nine variables as designed in the theoretical framework (except that 'perception of self-effectiveness'). The results indicate that individual education level, knowledge about renewable and belief about costs are significantly associated with individual willingness to pay. However, via an auxiliary regression test, the variable 'individual education level' was found to be significantly related with individual 'age', 'income' and 'knowledge about renewable energy', and it is proved that entering of this variable will lead to negative effects on statistical significance of other explanatory variables; in light of this, we estimated the other model (model 2 in Table 3.3) with the variable 'education' removed and the results present some improvement of the model. Effects from four variables are proved to be significant, age, household income, knowledge level and belief about RE costs. The sign of coefficients can be used to interpret the effect of independent variables on the probability of the occurrence of positive willingness to pay. The positive sign of the coefficient for the knowledge variable suggests that people who know well about renewable energy, as expected, are more likely to be positive towards acceptance of high-priced renewable electricity. Similarly, enhancive belief about costs of renewable energy use also would increase the possibility of a positive willingness to pay. A potential explanation for this may be that respondents who know well about costs increased by renewable energy use could understand why they should pay extra for renewable electricity, and tend to show a positive attitude. Hence, necessary information is needed to improve people's knowledge about energy, environment and their understandings about costs of renewable energy use. Enhanced knowledge and belief (about renewable energy cost) will greatly increase the resident's readiness to support for the deployment of renewable energy (willingness to pay extra) in rural areas. The negative coefficient of age indicates that young people are more likely to accept an extra payment for renewable electricity than old people. Income also shows significant effects on the possibility of the occurrence of a positive willingness to pay. People with higher income are inclined to pay extra for renewable electricity. Similarly with previous studies (Zografakis et al., 2010; Ek, 2005; Roe et al., 2001), these results may make sense since young people may accept new things more easily and household income indeed is an important determinant of family energy expenditure (and willingness to pay more). Following this regression model, we also calculated the marginal effects of independent variables (at the sample mean of the data) on the probability of occurrence of positive willingness to pay, as shown in the Table 3.3 (the last column). It proves that except the age variable, other three variables present significant and positive marginal effects, and amongst these in particular, the change of the knowledge level will cause most obvious change of the probability of a positive willingness to pay. The coefficients and marginal effects of other variables tested in this model, however, are not statistically significant.

Table 3.3 Logit regression results of willingness to pay more for renewable electricity

Independent variables	Model 1		Model 2		
	Coefficient	z-Statistic	Coefficient	z-Statistic	Marginal effect(dy/dx)
	McFadden R-squared: 0.18521; Prob(LR statistic): 0.00002		McFadden R-squared: 0.16825; Prob(LR statistic): 0.00003		
Intercept	2.956***	2.795	3.630***	3.705	-
Age	-0.197	-1.077	-0.370**	-2.429	-0.043**
Belief about cost of RE use	0.401*	1.948	0.440**	2.167	0.051**
Household income	0.291	1.278	0.404*	1.817	0.047*
Knowledge about RE	0.543**	2.132	0.628**	2.526	0.072***
Education	0.477*	1.814	-	-	-

Concern with environment	0.284	0.636	0.164	0.375	0.020
Gender	-0.376	-0.866	-0.119	-0.293	-0.014
Belief about benefit from RE use	0.132	0.739	0.105	0.590	0.012
Perception of neighbors' participation	-0.370	-0.711	-0.422	-0.822	-0.044

Note:* Significant at 10% level. ** Significant at 5% level. *** Significant at 1% level.

3.4.3. Participation intention of local residents and policy demand

One of the biggest differences between rural and urban residents in terms of renewable energy use may be the possibilities of public participation. Rural households could be both energy consumers and suppliers. One typical example is household biogas utilization, which refers to rural households participating in biogas production at the mean time of being biogas consumers. Consumer participation is an important element that should be considered when discussing the concept of social acceptance. Despite we did not distinguish different renewable technologies but test a general public acceptance in rural areas, in an attempt to know the intention and preferences of rural households regarding participation in renewable energy provision, we also surveyed their responses taking biogas production as an example. Such a selection is because first, not every kind of renewable energy use could be consumer involved, and aiming at general renewable energy could not answer this question; second, biogas is the most familiar renewable energy utilization to rural residents (its development even started from the early twentieth century (Gao et al., 2006)), and household biogas may be the most typical renewable energy use with absolute public participation. We included questions in the questionnaire about rural residents' preferences for participation in biogas energy provision.

Figure 3.7 gives the results indicating their preferences. We can find nearly a half of the respondents would rather be a biogas buyer only using this kind of energy provided by energy enterprises or governments. It suggests rural residents highly rely on energy supply managed or supervised by governments. This result can be partially explained by the particularity of biogas utilization. Household biogas use is time and labor-consuming in its daily operation and maintenance, which was also found to be the main reason why some residents stopped to use household biogas in early year. However, this result indicates that similar renewable projects probably would be more stable and efficient if they are managed or operated by governments rather than others. In the other words, the diffusion of renewable energy in rural areas would be impossible without government support or reasonable policy mechanisms. Policies in terms of information (knowledge) diffusion, financing and technical support should be emphasized to promote an effective deployment of renewable energy in rural areas.

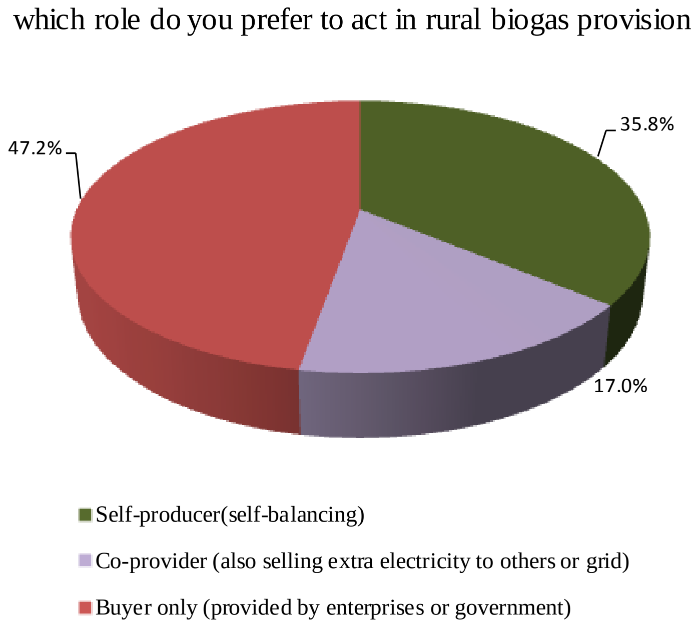

Figure 3.7 Preferences for participation in rural biogas provision

With high degree of support for renewable energy deployment, rural residents also stated the existence of some barriers during deployment of biogas or solar energy utilization. Afterwards they are asked to choose potential and relative rural energy policies that they suggest to be given attention. As shown in Figure 3.8, enhancing relative information communication was identified as the first priority by about 80% of the respondents; increasing investment and subsidies and enhancing technical support were also recognized as key policy demands which would be beneficial for the deployment of renewable energy in rural areas.

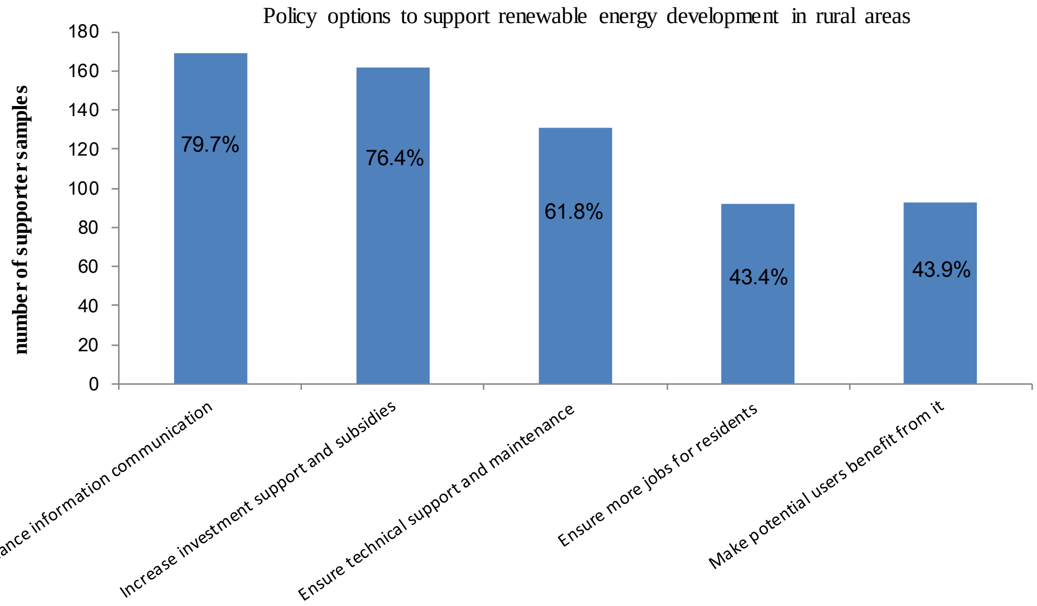

Figure 3.8 Rural policy demand for renewable energy deployment

3.5. Concluding remarks

This paper examines the general local acceptance of renewable energy deployment in rural areas of China. We also try to identify possible factors influencing the respondents' willingness to pay more for renewable electricity. Rural residents are found to be generally supportive to renewable energy development. Most of the respondents showed positive willingness to pay more for renewable electricity, and the probability of occurrence of such a positive intention is found to increase with household income, individual knowledge level and belief about costs of renewable energy use but decrease with individual age. Hence, the implications for policy makers are that propaganda and popularization of knowledge about renewable energy use would be conducive to win local public support.

The results are to some extent consistent with previous research on the similar topics. For instance, Yuan et al (2011) also proved a considerable high level of social acceptance of solar water heater (but not for solar PV) and income, age and education of residents play a role in this level of awareness and decision to implement solar technologies at home. It suggests that a general support for renewables development proved by our research is also closely associated with the popularization of solar water heater and biogas use in rural China.

There are also some limitations of this study. Relatively small number of usable samples was collected for statistical analysis. Additionally, three villages selected located quite closely with similar economic and geographic background, thus we did not look at the differences between regions and their possible impacts on public acceptance. Future studies shall pursue to close these gaps by expanding the survey scope. It also should be noted the stated willingness is not actual payment, people's consciousness of stating something they deem as being perceived as the right answer but not necessarily real intention may to some extent affects their answers, which but is inevitable in this type of social survey. Aimed at examining the general acceptance of rural renewable energy deployment, this paper would provide some references for the target or strategy setting of developing renewable energy in rural areas. While different technologies (to supply energy) have various effects with varying costs and benefits, it would be the focus in subsequent research to discuss the development of concrete and different renewable technologies.

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Chapter 4. Energy consumption practices of rural households in north China: basic characteristics and potential for low carbon development [15]

Abstract

Reducing the climate impact of rural household energy consumption in China is complicated since it is bound up with deeply routinized daily practices and dependent from existing infrastructural systems of energy supply. To assess the potential for low carbon development we first estimate the overall CO_2 emissions of rural households, followed by a more in depth description and characterization of the different energy use practices within the households. Space heating turns out to be the largest emission source among domestic energy practices in north China. We present lifestyle and context related factors that help to explain existing differences in domestic energy use practices of households. The potential for low carbon development is discussed both at the demand side and the supply side. At the demand side, the use of more efficient technologies and cleaner energy sources for space heating seems to be a high potential measure for achieving low carbon households. At the supply side the reduction of rural domestic CO_2 emissions could be effectively supported by making available to householders renewable and cleaner energy sources and technologies. In order to be effective, such low carbon energy options should take into account the (income) characteristics and lifestyles of rural householders.

Key words:
Rural China, low carbon households, domestic energy use practices.

4.1. Introduction

In China, almost one half of the population lives in rural areas. They are usually

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characterized as being “confronted with economic poverty, with heavy reliance on biomass, leading to damage to ecological environment, etc.” (Zhang et al., 2009). All these features are linked one way or another with the energy usage of rural households. When compared to urban households, the energy consumption of rural households has received limited attention of researchers and policy makers. Reducing the climate impacts of the energy consumption of rural households can be considered as an important instrument and strategy for climate change mitigation. Moreover, the continuous increase of total and per capita energy consumption in rural areas indicates the urgency to look at possibilities for the mitigation of rural carbon emissions. As yet however, carbon emissions in rural areas - characterized most of the times by ecological systems that are particularly vulnerable for the consequences of climate change - are not specified for their composition and their potential contribution to low carbon development.

The pattern of energy use of rural households seems to be more complicated when compared with urban households. Both kinds of households show similar sets of daily practices of energy consumption, like cooking, heating, cooling, and transport. However where urban householders are connected to (energy) infrastructures that provide households with energy in a standardized, eco-efficient and regular manner, rural households most of the times lack such a standardized provision. They instead are faced with locally specific options, some of which bring along considerable investments of both time and labor from the side of the householders. They rely to a large extent not just on local resources (wood, straw, biogas installations, etc.) but are dependent as well from local energy providers that offer little guidance for energy saving and climate change mitigation at the domestic level.

In this article, we analyze in some detail the energy consumption patterns of rural household and examine the potential for reduction of GHG emission and for a ‘low carbon transition’ in the area of rural domestic energy use. First we discuss the aggregate energy consumption of Chinese rural households as addressed by a number of previous studies (Chen et al., 2006; Cohen et al., 2005; Jiang and O’Neill, 2004), and examine the influence of some household characteristics (income, education, etc.) on the carbon emissions. Second we address the nature of the energy consumption practices within Chinese rural households. So far, hardly any study has addressed the question what actually happens within rural households in terms of the existing energy consumption routines that are enacted by the householders in their everyday life. With this study, we try to ‘open up the black boxes’ of Chinese rural households as far as their energy behaviours are concerned. We try to ‘unpack’ the household energy consumption both in terms of the different practices of energy use (cooking, heating, cooling, lighting the house, transport) as well as in terms of the different sources of energy (coal, electricity, firewood, straw, biogas, etc.) used for these practices, and the carbon emissions resulting from these energy use practices. Finally, by linking the choices made in the black box - the households - with their relevant context - the local systems of rural energy provision - we explore how (future) decision making of households on low carbon energy consumption is co-determined by factors that are outside their sphere of influence. Our reconstruction and analysis of the 'energy-use profile' of rural households in China makes it possible to suggest some policy interventions for mitigating the carbon footprint of Chinese rural households.

4.2. Conceptual framework and research methodology

4.2.1. The concept of a low carbon rural development

It had been commonly believed that, along with economic development, societies especially in developing countries undergo an "energy transition" in which households generally choose to switch from traditional biomass fuels to more convenient energy sources such as electricity, liquefied petroleum gas (LPG) and more efficient energy systems for their domestic energy needs. This transition has been conceptualized in the form of the "energy ladder" (Leach, 1992; Kirk et al., 1994) and is proved to follow different pathways in different countries. For instance, some studies on China and India confirmed the prediction of the "energy ladder" theory by showing that households shifted to more convenient, cleaner and more efficient modern energy sources due to the rapid increases in the levels of urbanization and economic development (Cai and Jiang, 2008; Pohekar et al., 2005; Dhingra et al., 2008). Until a decade ago, the energy ladder served as the prominent model for explaining household energy choices in developing countries (Elias and Victor, 2005). Since the turn of the millennium however, its validity has been questioned by a number of studies (Masera et al., 2000; Heltberg, 2004; Bhutto et al., 2011). It has been suggested that, instead of switching between fuels, households choose to use a combination of both fuels and conversion technologies. This process of diversifying their energy sources is referred to as switching to multiple fuels, resulting in a so called "fuel stacking" model. This model predicts that, when a modern fuel is adopted, traditional fuels and devices are still (at least temporarily) kept in place or in store, so that it can be concluded that households make the shift or transition only gradually and partially (Kowsari and Zerriffi, 2011). Empirical studies on many developing countries (Jiang and O'Neill, 2004; Masera et al., 2000; Heltberg, 2005) and even from developed countries (Paul et al., 2006) show results that fit well into this fuel-stacking model. Whatever model Chinese rural households may follow when going through the process of modernization that results from higher incomes and increasing levels of consumption, this transition always implies higher levels of energy consumption and therefore a potentially higher impact in terms of carbon emissions. The challenge for rural households is to find ways to combine economic development with reduced pressures on the environment. This is the meaning of the concept of a 'low carbon development for rural households'.

4.2.2. The social practices model for studying domestic energy consumption

When investigating the potential for a low carbon energy transition it is important to first establish the levels of energy consumption by rural households and to relate these overall levels with relevant background variables such as household incomes. Second, it is important to explore in some detail the energy profiles of rural households in terms of their composition. The rural 'domestic energy profile' needs to be specified in terms of what practices are enacted, how much energy is needed for this, and from what different energy sources this energy is derived. To make possible such a detailed analysis of the internal rural household energy systems, we suggest using the 'social practice approach' as developed in the sociology of consumption (Spaargaren, 2003; Van Vliet, 2002) and shown in Figure 4.1. At the right-hand side of the model, a system for energy production and provision is depicted to indicate the relevance of these systems for the analysis of domestic energy consumption practices. It is important to find out what kind of choices households have when it comes to using certain energy sources for their daily consumption practices. So for instance when no firewood is around or within reasonable distance, there will not be much cooking with firewood going on. When biogas-programs are strongly pushed by the local government, this enhances the chance that people might use biofuels for cooking, etc. So the system of provision offers a certain 'configuration of choices' available for (low and middle income) households in a certain village or city, which must be taken into account when studying the actual energy-choices made by households.

In the center of the model, there are a number of socio-economic energy practices referring to the organized and routinized activities of domestic consumers. In this research we inspect household energy consumption in relation to the domestic practices of cooking, space heating, water heating, lighting and cooling the house, transportation, as well as different forms of leisure and entertainment. These practices are shaped by social and economic dynamics. They result from decisions made by households against the background of the configuration of choices made available to them by the (local) systems of provision.

Not all households however react in similar ways to the economic, social and ecological conditions they are confronted with. That is why at the left-hand side of the model, there is mentioning of the lifestyles of householders. Lifestyles are comprised of the activities and routines that are performed by households, while also reflecting their members' attitudes, values or worldview (Spaargaren and Oosterveer, 2010). In other words, actual lifestyles of householders are considered as resulting from some general values, opinions and (historical) experiences of the householders on the one hand, while being influenced by the set of consumption practices they are presently involved in on the other.

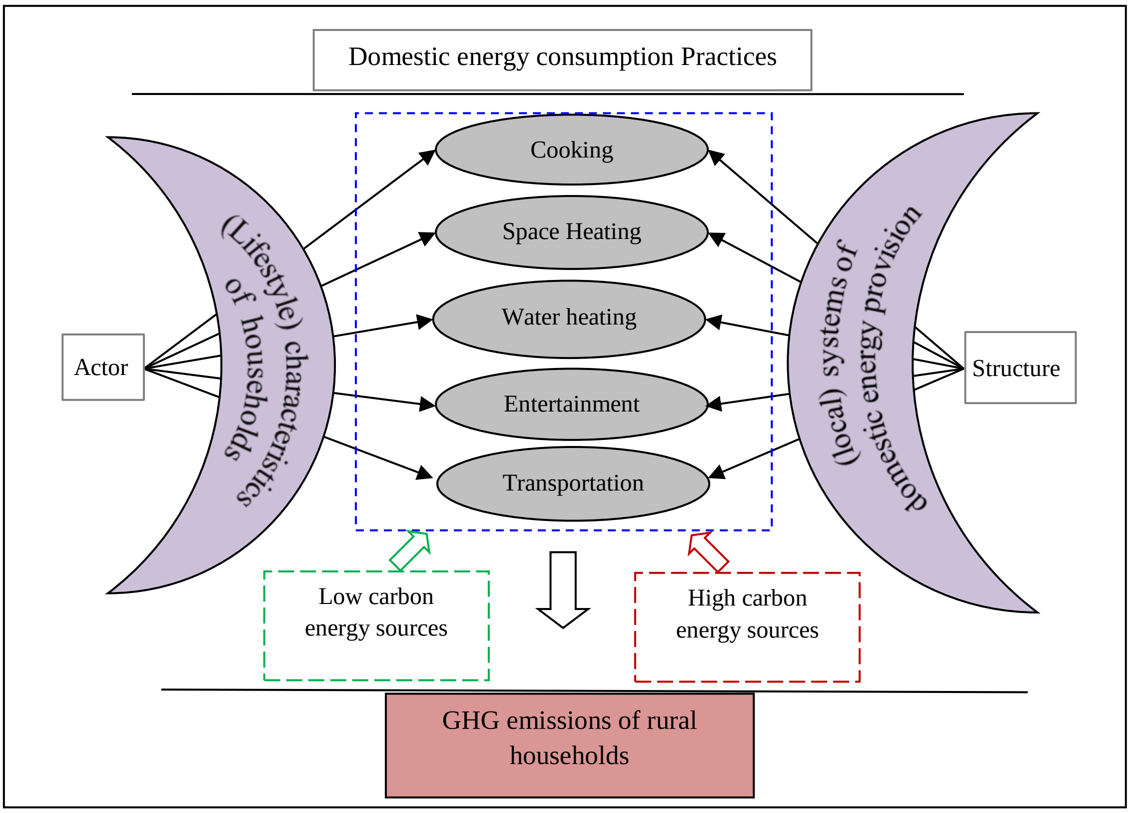

Figure 4.1 The social practice model for rural household consumption

As indicated in Figure 4.1, the set of domestic consumption practices can be fueled by high or low carbon energy sources, resulting in a higher or lower overall score in terms of the GHG emissions of rural households.

4.2.3. Selection of the rural areas and the respondents

Considering the fact that energy consumption tends to rise with an increase of household income, living standard and urbanization level (Cohen et al., 2005; Jiang and O'Neill, 2004), we assume that a low carbon transition is particularly relevant for the richer rural areas. For that reason we selected a relatively well-off rural area in north China for the field survey. We choose Shandong province to examine household energy use practices and to assess the quantity and composition of the carbon emissions they bring along. Shandong has almost 90 million inhabitants and has the third largest GDP in China. The agricultural population accounts for more than 59.8% of the (registered) provincial population in 2010, so that rural areas can be expected to play an important role in the energy transition in this province. Based on some consultations with local officials from Shandong, Zibo city was considered to be appropriate for this research and selected to conduct a questionnaire survey (see Appendix II the questionnaire). This city governs five districts, among which the Zhoucun district that was selected as the sample areas. Zhoucun[16] is famous as the birthland of Lu Business (one of the five most famous Business Groups in Chinese history) with an area of 307 km^2 and a population of 343,000. The district administers five towns that together cover 257 administrative villages. At present there are 125,000 rural inhabitants in Zhoucun who possess 156.7 thousand mu[17] farmland and 46.3 thousand mu of forest land in total. They are not very rich in terms of cultivated land, thus the agricultural sector only occupies a tiny part in the whole economy (with the primary sector accounting for 3.6% of GDP in 2010). Rural net income per capita was 9,576 Yuan which is about 62% higher than the national level rural incomes (all in Chinese currency)[18].

We selected four villages and conducted a questionnaire survey in August 2011. As shown in Table 4.1, these four villages with diverse scales are administered by two towns, located around central Zhoucun district. It shows that the cultivated land per capita is only around 1 mu. Due to the availability of rich mineral resources and a relatively well developed industry in this area, rural households mainly make their living not from agriculture but from some local industries. In most households income from labor comes from members working in local factories nearby.

[16] Following information is from: Zhoucun economic and social development statistical bulletin in 2010
[17] Chinese acre land measurements with one mu equal to 1/15th of a hectare (the same as below).
[18] Data sources: National economic and social development statistical bulletin in 2010

Table 4.1 Basic information of the surveyed areas and samples

Items	Nanjiao Town		Wangcun Town		Total
Villages	Dongchen village	Liujia village	Lijiatuan village	Pengjia village	-
Registered Populations (person)	816	306	1200	1600	3922
Number of households	263	103	302	485	1153
Distance from Zhoucun district (km)	3	5	20	13	--
Cultivated land per capita (mu)	0.95	1.1	1	1.1	1.04
Average members of each household[19]	3.10	2.97	3.97	3.30	3.40
Number of surveyed households	39	38	53	35	165
Average size of sample households	4.21	3.76	3.57	3.46	3.74
Average age of sample household members	43.91	41.78	42.53	44.37	43.07
Average education level of samples (years)	8.81	8.09	7.82	7.14	7.97
Average income per capita in 2010 (Yuan)	21369.4	10330.0	13501.4	11442.0	14193.9

Data sources: the field survey.

Households were randomly selected by interviewers with about 40 households being interviewed in each village. The survey was carried out by direct interviews towards target respondents with each question given detailed explanations by the interviewers (seven in total). A total of 165 valid responses were obtained. The sample accounts for 14.3% of the total number of households in these four villages. Data was processed using SPSS which gives some statistical descriptions as presented in Table 4.1.

4.2.4. Methods to calculate the CO_2 emissions

The calculation of the CO_2 emissions of rural energy consumption is especially complex due to the lack of available data and normative methods for accounting rural carbon emissions. Data availability may be the biggest problem, since there are no data of, for instance, the amount of traditional biomass used for daily consumption or the amount of electricity that is used for the different daily practices as they are distinguished in our conceptual model. So for the assessment of the carbon emission of each energy consumption practice, we have to adopt some methods to arrive at reliable estimates. A number of methods

[19] This data is calculated according to statistics on registered population; it is different from the statistics on average size of sample households, because the latter one is based on the survey on real number of household members.

and related considerations will shortly be discussed below.

CO_2 emission from commercial energy (coal, LPG, gasoline) is accounted by the most widely used methodology provided by the IPCC (2006), as shown in the following equations:

$$E_h = \sum_{i=1}^{n} EF_i \times C_i \quad (1)$$

$$EF_i = CEF_i \times NCV_i \times OR_i \times 44/12 \quad (2)$$

Where:

E_h: Household CO_2 emissions (t)

EF_i: CO_2 emission factor for fuel i（t CO_2-eq per fuel unit）

C_i: Consumption of fuel i (fuel unit)

CEf_i: Carbon content of the fuel i (t C/TJ)

NCV_i: Net calorific value of fuel i (TJ per fuel unit)

OR_i: Oxidation rate of fuel i (percent)

It should be noted that the oxidation rate of coal was assumed to be 80% (Zhang et al., 2008), considering the low efficiency of coal stoves used in rural areas, and for other fuels (LPG, gasoline) we assumed 100% oxidation rates. Since we aim to estimate CO_2 emissions of final energy consumption, emissions from electricity consumption have to be taken into account as well. Calculation of emissions from electricity use complied with Eq. (1); only the emission factor of electricity is different from other fuels. The operation marginal emission factor (0.9914 kgCO_2/kWh)[20] of north China Grid in 2010 is adopted.

It should be mentioned that biomass fuel (straw, firewood) is another fuel source consumed by some rural households for their daily life. But carbon emission from biomass use is not calculated and included here, since biomass fuels are usually recognized as being carbon neutral, which is based on the argument that the creation of that biomass has removed as much CO_2 as is emitted during its combustion (Rabl et al., 2007). It is a controversial issue, because it may be argued that CO_2 emitted during the whole lifecycle of biomass may not simply equal the amount that it removes.

4.2.5. Estimation of electricity consumption for different energy use practices

From the field survey, we obtained data on the household consumption of electricity, coal,

[20] Data source: "2010 baseline emissions factors for regional power grid in China" available at: http://cdm.ccchina.gov.cn/WebSite/CDM/UpFile/File2552.pdf

LPG and gasoline. Some energy carriers are used for one particular practice only (see Table 4.4): LPG is only used for cooking and gasoline is only used for transportation. Coal is used especially for space heating, with coal-based cooking and water heating only taking place simultaneously with space heating in the winter. Electricity, on the other hand, is used for several practices, and households are generally not able to distinguish what share of electricity is used for which practice. Because we possess data on total electricity use and on the practices for which electricity is used by each household, and because there is considerable variation between households in the practices for which electricity is used, we can estimate the contribution of each practice to total electricity use by means of a regression analysis.

When we distinguish household electricity consumption for households of different sizes, we observe a positive relationship between household size and electricity consumption, and a negative relationship between household size and per capita electricity consumption.[21] The latter finding suggests that there are important scale advantages in electricity consumption. We therefore specify a double-logarithmic function for the relationship between electricity consumption and household size, and expect the coefficient of household size to be positive but smaller than one. Dummy variables are added to this model for each energy practices. The coefficients of these dummy variables can be interpreted as the percentage contribution of each practice to electricity consumption for a given household size. Hence, the model that we use for estimating the contribution of each practice to total household energy consumption is as follows:

$$\log(EC_i) = C_0 + C_1\log(Size_i) + C_2D_{CK,i} + C_3D_{CL,i} + C_4D_{HT,i} + C_5D_{TR,i} + C_6D_{WT,i} + C_7D_{LT,i} + C_8D_{ET,i} + \varepsilon_i \quad (3)$$

Where:
EC_i: Electricity consumption of household i (in kWh);
$Size_i$: Size of household i.

$D_{CK,i}$, $D_{CL,i}$, $D_{HT,i}$, $D_{TR,i}$, $D_{WT,i}$, $D_{LT,i}$, $D_{ET,i}$: Dummy variable that equals one if household i uses electricity for cooking, cooling, space heating, transportation, water heating, lighting and entertainment, respectively, and zero otherwise.

All households in the sample use electricity for lighting and entertainment, so the data set does not allow us to estimate the separate contributions of lighting and entertainment to total

[21] Results are available upon request from the first author.

household electricity consumption. Similarly, nearly 99% of the households use electricity for cooling in the summer time (either with fans or an air conditioner). These three practices are therefore excluded from the regression analysis.

Table 4.2 Regression results for electricity consumption

Variables	Coefficient	t-value	Coefficient	t-value
Constant	5.73***	29.3	5.72***	29.4
Household size	0.776***	5.99	0.773***	6.17
Cooking	0.374**	2.52	0.371**	2.58
Space heating	0.287*	1.88	0.288*	1.89
Transportation	-0.009	-0.09	-	
Water heating	0.191**	2.18	0.191**	2.19
R-square	0.323		0.323	
Adjusted R-square	0.297		0.304	

Note:* Significant at 10% level. ** Significant at 5% level. *** Significant at 1% level.

The regression results are presented in the second and third column of Table 4.2. The estimated coefficient for the household size variable is highly significant and smaller than one, which confirms that there are important scale advantages in electricity consumption for larger households. The estimated coefficient for transportation is not significantly different from zero, suggesting that its contribution to total electricity use of households is negligible. A possible explanation is that electric bicycles are especially power saving. On average one electric bicycle consumes about 1.2 kWh per 100 km (Ni, 2008). Moreover, the survey villages are relatively compact. Most households and even the factories where people work are located close to each other. So, electric bicycles may not be used for a long time or for long distances, even though up to 70% of the households in these villages own an electric bicycle.

In the last column of Table 4.2, we re-estimated the model with the dummy variable for transportation excluded. All estimated coefficients are significantly different from zero (at a 10% testing level). The estimated value of 5.73 for the constant indicates that the electricity consumption from lighting, entertainment and cooling (and transportation) equals 308 kWh in one-person households. The estimated coefficient for the cooking dummy variable indicates that electricity use is 45% higher in households that use electricity for cooking. Likewise, it is 33% higher for households who use it for space heating and 21% higher for those who use it for water heating.

We used this result of the regression analysis in our calculation of the energy consumption for different practices (section 4.4.1). Since three practices (lighting, entertainment and cooling) are estimated and reflected in the intercept in our estimations of electricity consumption per practice, they are treated as a package in those calculations.

4.3. Domestic energy consumption: the general picture

There are many studies available on rural energy consumption, particularly on energy use in the developing world. In general these studies focus either at the total domestic energy consumption or at some specific energy use activities. For instance, many studies depict the overall energy situation of rural households with the use of descriptive statistic analyses (Zhou et al., 2008; Miah et al., 2010, 2011; Madubansi and Shackleton, 2006; Wang and Feng, 2001, 2005; Fan et al., 2011) which are either taken from national (local) statistics or based on field survey data. They also examine factors determining household energy choices using econometric analysis (Komatsu et al., 2011; Jiang and O'Neill, 2004; Fan et al., 2011; Ouedraogo, 2006; Chen et al., 2006) showing that there are a number of factors affecting the energy portfolio of the household. Factors which are proved to be relevant in this context are household size, household composition (of gender or age) and education (Jiang and O'Neill, 2004; Farsi et al., 2007; Gupta and Kohlin, 2006; Heltberg, 2005). A large amount of studies identify income as being the major driver behind the uptake of modern fuels (Komatsu et al., 2011; Joon et al., 2009; Fan et al., 2011; Jiang and O'Neill, 2004; Ouedraogo, 2006). Besides the economic and demographic characteristics, also socio-cultural factors such as cooking habits and domestic lifestyles (Joon et al., 2009; Gupta and Kohlin, 2006; Heltberg, 2005) are mentioned as relevant factors influencing energy consumption. Finally, external conditions such as resource endowment, access to modern energy technologies and the policy environment are pointed out to have important effects as well (Fan et al., 2011; Jiang and O'Neill, 2004). Computational models are applied by some scholars who take rural household energy use as a system and establish models either for optimization or for forecasting and assessing supply and demand of domestic energy (Ppkharel and Chandrashekar, 1997; Howells et al., 2005; Jebaraj and Iniyan, 2006; Howells et al., 2002; Limmeechokchai and Chawana, 2007). These studies mostly focus on energy usage technologies and their characteristics. In recent years, since sustainable rural development is being discussed in various fields, some studies started to look into renewable or sustainable energy utilization such as biomass, biogas and solar energy. Most of the times, economic and environmental impacts of these sustainable energies are assessed and discussed as solutions to alleviate poverty, mitigate climate change and limit the damage to local ecosystem (Limmeechokchai and Chawana, 2007; Nguyen, 2007; Byrne et al., 2007; Chen et al., 2010_b; Li et al., 2009; Bhutto et al., 2011).

Building upon and contributing to this body of literature, we used our data to investigate the potential factors affecting the aggregate CO_2 emissions of rural households using a double-logarithmic regression analyses as shown in Eq (4). Taking previous studies as our references (Jiang and O'Neill, 2004; Chen et al., 2006), we estimate the impact of age, education, household size, income, and ownership of air conditioners on household CO_2 emissions. Taking into consideration that rural biomass use is considered by many scholars to be a key element in the rural energy transition, we also use a logistic regression (Eqs (5) and (6)) to examine the impact of the same explanatory variables on the use (versus non-use) of traditional biomass. The dependent variable was set equal to one if traditional biomass was adopted, and zero otherwise:

$$\log(E_i) = C_0 + C_1 Age_i + C_2 Edu_i + C_3 \log(Inc_i) + C_4 Size_i + C_5 Own_i + \varepsilon_i \quad (4)$$

$$P(Y=1) = \exp(z) / (1+\exp(z)) \quad (5)$$

$$z = C_0 + C_1 Age_i + C_2 Edu_i + C_3 \log(Inc_i) + C_4 Size_i + C_5 Own_i + \varepsilon_i \quad (6)$$

Where:

E_i: CO_2emissions of household *i*;

Age_i: average age of members of household *i*;

Edu_i: average education years of members of household *i*;

Inc_i: income per capita of household *i*;

$Size_i$: size of household *i*;

Own_i: ownership of air conditioner of household *i*;

P: the probability of traditional biomass adoption (Y=1).

The results of the two regression models are shown in Table 4.3. Household carbon emissions are positively correlated with the five explanatory variables. When the average age of household members is higher, the household is likely to emit more CO_2 as a result of daily energy consumption. This may be because older people perhaps demand more energy consumption for their daily practices such as space heating and water heating. Households with higher (average) educational level show higher emission levels as well, possibly due to the fact that people with better education pursuit a higher quality of life. Household emissions are also found to increase with household income level and with household size. Households with higher incomes can afford to consume more commercial energy, which in turn leads to larger carbon emissions. The income elasticity of household carbon emissions equals 0.25 for the households in our data set. Finally, we find that households possessing air conditioner(s) will emit 7% more CO_2 than those who do not. This finding is consistent with previous studies that found similar results. Ownership of some large appliances intensifies emissions.

Different from the linear regression model, the five explanatory variables are found to have a negative impact on the adoption of traditional biomass fuels although the estimated coefficients of household size and air conditioner ownership are not statistically significant. These results indicate that households with higher educational level and higher income level are more likely to give up using traditional biomass fuels for their daily life. Higher education and household purchasing power makes households prefer and being able to consume more convenient and modern energy sources instead of traditional biomass. The marginal effect of income on the probability of adoption of traditional biomass fuels equals -0.53, which indicates that biomass is considered a highly inferior good. The age variable also shows a significant negative impact on the adoption of biomass. A possible explanation is that older people give up using biomass because of its inconvenience for instance during collection or combustion[22].

Table 4.3 Regression results of household carbon emissions and adoption of biomass

Variables	Household carbon emissions OLS linear regression		Use versus non-use of biomass logistic regression		
	Adjusted R square=0.4010; Prob(F-statistic)=0.0000		McFadden R square=0.1213; Prob(LR statistic)=0.0002		
	Coefficient	t-value	Coefficient	t-value	Marginal effects
Intercept	2.2756***	8.9699	12.6809***	3.5631	-
Age	0.0036**	2.2484	-0.0364*	-1.7826	-0.0090*
Education	0.0121*	1.6767	-0.2534***	-2.6292	-0.0630***

[22] We also estimated binary logit models of the adoption of household solar energy and biogas using the same five explanatory variables, but in both equations none of these variables was found to have a statistically significant impact.

household income	0.2529***	4.7280	-2.1276***	-2.8383	-0.5251***
Household size	0.0926***	6.9211	-0.2347	-1.3693	-0.0582
Ownership of air conditioner	0.0704**	2.1554	-0.2081	-0.5072	-0.0515

Note:* Significant at 10% level. ** Significant at 5% level. *** Significant at 1% level.

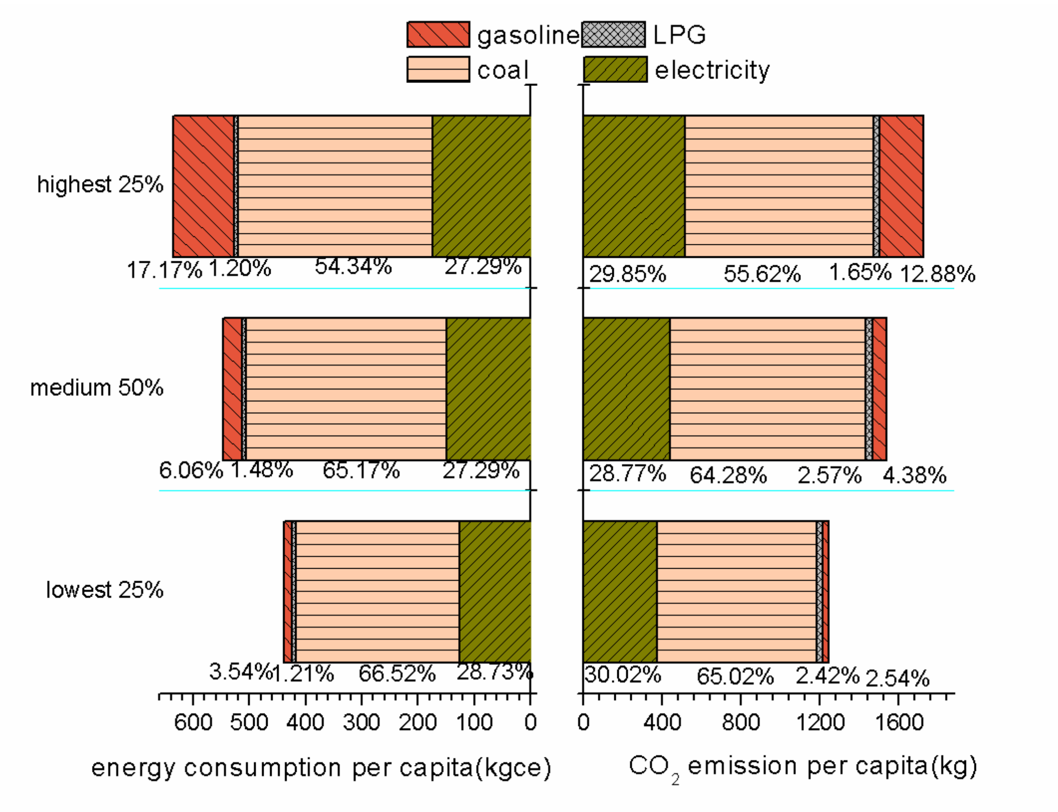

Figure 4.2 Energy consumption and carbon emission of three different income groups

Since household income is found to have a significant impact on total CO_2 emissions of rural households, we categorized the sample households into three income groups and compared the structure of energy consumption and carbon emissions for these groups. The results are shown in Figure 4.2. Besides the differences in total energy consumption and emissions between these three income groups (higher income group consumes more energy with higher carbon emissions), we can also observe some structural differences. There is not much difference in terms of electricity and LPG consumption between the groups. But there are important differences in the contributions of coal and gasoline, especially when we compare the lowest 25% with the highest 25% income group. Coal consumption (and emission) contributes more in the lower income group, while gasoline consumption (and emission) contributes substantially more in the higher income group. This might indicate that an increase in rural income in the future brings along an increase of energy consumption and emission connected to rural transportation in particular.

Having discussed the nature of domestic energy consumption of rural households in the Zhoucun district in China at the general level, we in the next section take a further look inside the households. By discussing energy consumption and CO_2 emissions not at the aggregate household level but at the level of distinct social practices, we are able to 'open up the black box' of rural domestic energy consumption.

4.4. Rural domestic energy practices and their relation with the low carbon transition

In this section we explore in some detail the relationship between rural domestic energy practices and the potential for a low carbon transition in rural China.

4.4.1. Domestic energy use practices and carbon emissions

It is common for rural households to adopt a multiple fuel (and diverse devices) strategy even for one daily practice. We discuss the energy sources used for different domestic energy practices in some more detail. To start with the practice of 'cooking', we found from the survey results as shown in Table 4.4 that electricity is an important energy source in this practice. The next important energy source for cooking is LPG, used by 77.6% of the households. Traditional biomass stoves are still used by 37.6% of the households, and also biogas and natural gas[23] were used by certain families. In a similar manner, we found combined or multiple fuel-use for the practices of 'water heating', including coal, electricity as well as solar energy (47.9% of households). The practices of 'space heating' and 'cooling' were almost exclusively dominated by coal (with coal stoves being installed in 95.8% of the households[24]) and electricity respectively. With convenient electricity connections being in place in these areas, electricity serves as a major energy source for almost all types of domestic practices. For the practice of 'daily transportation' 70% of the rural households in our sample report to use electric bicycles.

[23] There have been a few residential buildings in Dongchen village and Lijiatuan village. People living in these buildings use natural gas for cooking and space heating.

[24] Coal stove was a major source for space heating during the winter and widely used in the sample areas; the stove itself can be used for cooking or water heating, meanwhile heat can be transferred via pipes connected with the living room and bed rooms.

Table 4.4 Energy carriers and devices used for different practices by the households

Energy carriers	Energy use devices	Cooking	Space heating	Cooling	Water heating	Lighting	Entertainment	Transportation
straw &firewood	biomass stove	37.6%	2.4%	-	18.2%	-	-	-
coal	coal stove	46.7%	95.8%	-	60.0%	-	-	-
electricity	cooking appliances	88.5%	-	-	0.0%	-	-	-
	air conditioner	-	10.3%	36.4%	-	-	-	-
	fan	-	-	96.4%	-	-	-	-
	electric radiator	-	6.7%	-	-	-	-	-
	electric water heater	-	-	-	57.0%	-	-	-
	ordinary light	-	-	-	-	27.3%	-	-
	energy efficient light	-	-	-	-	93.9%	-	-
	TV	-	-	-	-	-	100.0%	-
	audio equipment	-	-	-	-	-	42.4%	-
	computer	-	-	-	-	-	47.3%	-
	electric bicycle	-	-	-	-	-	-	70.3%
LPG	LPG stove	77.6%	-	-	-	-	-	-
biogas	biogas stove	1.2%	-	-	0.6%	-	-	-
natural gas	natural gas stove	3.0%	3.0%	-	3.0%	-	-	-
solar energy	solar water heater	-	-	-	47.9%	-	-	-
gasoline	car or coach	-	-	-	-	-	-	23.0%
	motorcycle	-	-	-	-	-	-	64.2%
-	bus	-	-	-	-	-	-	20.6%
-	bike	-	-	-	-	-	-	49.1%

Note: the data in the table represents what percentage of sample households are using each energy use device.
Data source: the field survey.

The use of multiple fuels and energy conversion devices is more or less common among rural households. In the context of the low-carbon energy transition it is important to identify for each social practice which low carbon alternatives are available. A shift towards the use of low-emission energy sources would be one potential pathway for a low carbon transition, next to the introduction of new energy saving behaviours and/or the abandoning of certain high impact practices. As shown in Figure 4.3, we can sketch a rough comparison of the effects of using different energy sources for each domestic energy practice. The differences are based on the calculated emission factors. As for the practices of cooking, space and water heating, it is obvious that using energy sources like firewood, straw (combusted in a traditional way[25]) and coal results in much higher levels of carbon emissions than using cleaner sources such as electricity, LPG and natural gas. Renewable energy sources like biogas and solar energy can be regarded as low-carbon sources most of the times. With regard to the practice of transportation, it is found that the use of electricity driven means of transport result in lower carbon emissions than using gasoline. Driving a car is more carbon intensive than using an electric bike, and the shift from one transport modality to another seems to be a relevant choice for many rural households in the area of investigation.

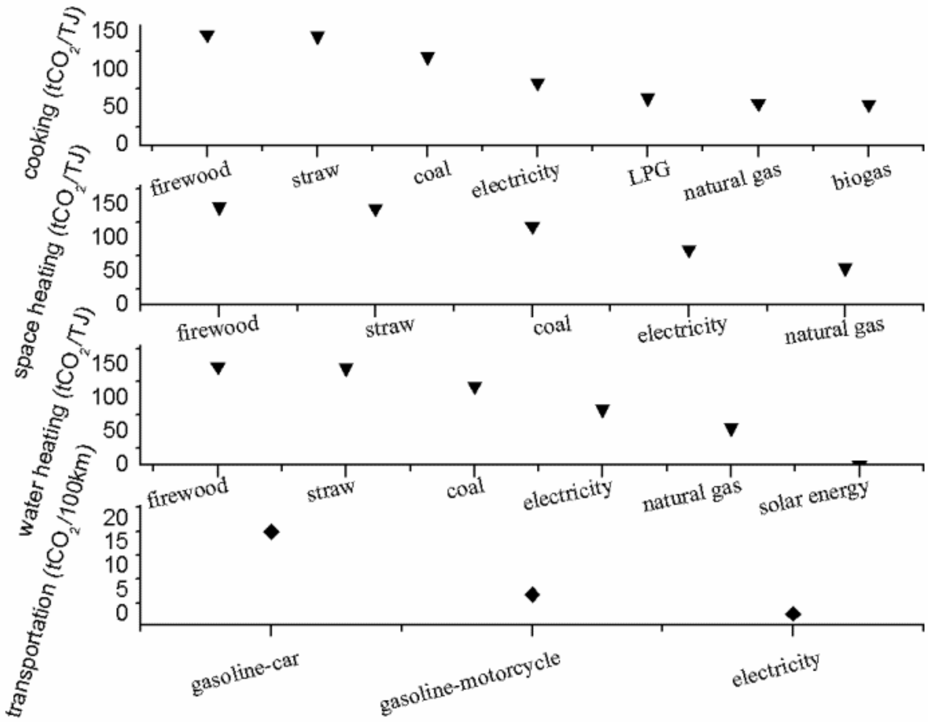

Figure 4.3 High- and to low carbon energy sources for domestic energy practices[26]

[25] It may be argued that biomass is carbon neutral as illustrated in section 4.2.4. However, here we do not consider its function as carbon sink, and we compare its emission factor with other end-use energy sources to identify which energy use has a relatively lower carbon factor.

[26] *Note 1*: We compare different energy uses based on their emission factor per unit heat (TJ). However, this may not always be appropriate since even for the same purpose, energy demand may not be the same -- for instance, to cook a bowl of rice, it may demand different amounts of heat energy when using a coal stove or an electric rice cooker. *Note 2*: The emission factor for each energy source is estimated based on the following assumptions: i) emission factors of firewood and straw are taken from Liu et al (2012) with the combustion efficiency of these traditional biomass assumed to be 60% (Chen et al., 2010$_a$); ii) emission factors of coal, LPG, natural gas and biogas (and gasoline) are the default factors from IPCC (2006); only combustion efficiency of coal is assumed 80%, as introduced in section 4.2.4; the others are 100%; iii) the emission factor of electricity is calculated based

When considering the shift to low carbon rural energy consumption, the next important question is how carbon emission levels for the different social practices relate to income levels. Using the regression results for electricity consumption (see Table 4.2), we calculate average carbon emissions from different energy use practices for different income groups. Lighting, cooling and entertainment are taking together, because our dataset does not allow an estimation of the electricity consumption for each of these three practices separately. As shown in Figure 4.4, it is proved that space heating is the largest emission source among all daily practices, but differently it accounts for around 64% of the total CO_2 emissions in the lowest 25% income group, and 59% in the highest income group. Cooking shows the same pattern when moving from the lowest to the highest income group, with a decrease of around 2% of the contribution to household carbon emissions (and a 1.2% decrease of the share in total energy consumption). On the other hand, water heating and transportation practices show obvious and opposite changes when moving from low income to high income groups. The contribution of transportation to household CO_2 emissions in the highest income group is more than threefold of that in the lowest income group. In a similar manner, the contribution of water heating to total CO_2 emission is higher for the top 25% income group when compared with the bottom 25% income group. Regarding the bundled package of the three practices (lighting, cooling and entertainment) the figures show slight differences between the two income groups, but it is difficult to identify which practice contributes most to the difference. The results indicate that along with the increase of income, rural households can be expected to pursue a higher quality of life or what Shove (2003) has labeled as higher levels of comfort, convenience and cleanliness. In the Chinese rural context this means that households want to consume more energy in the areas of consumption that are beyond the demands of basic living (cooking, space heating). With increasing income levels, the investments in practices like transportation and water heating are expected to rise, while the relative share of practices for basic living demand decreasing accordingly. In short, the energy profile of rural households in China is shown to change with increasing income levels, and this is reflected in their carbon footprint.

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on coal consumption per unit electricity generation in 2010 of China, and thus different from the one set in section 4.2.4, which makes it possible to be converted into the form of emission per unit heat; iv) solar energy is simply assumed to have zero emission; v) for transportation, the emission factor of gasoline and electricity (emission per unit fuel) is converted in the form of emission per 100 km, using parameters of common car (8L/100 km), motor bicycle (2L/100km) and electric bicycle (1.2 kWh/100km) (also see Ni (2008)).

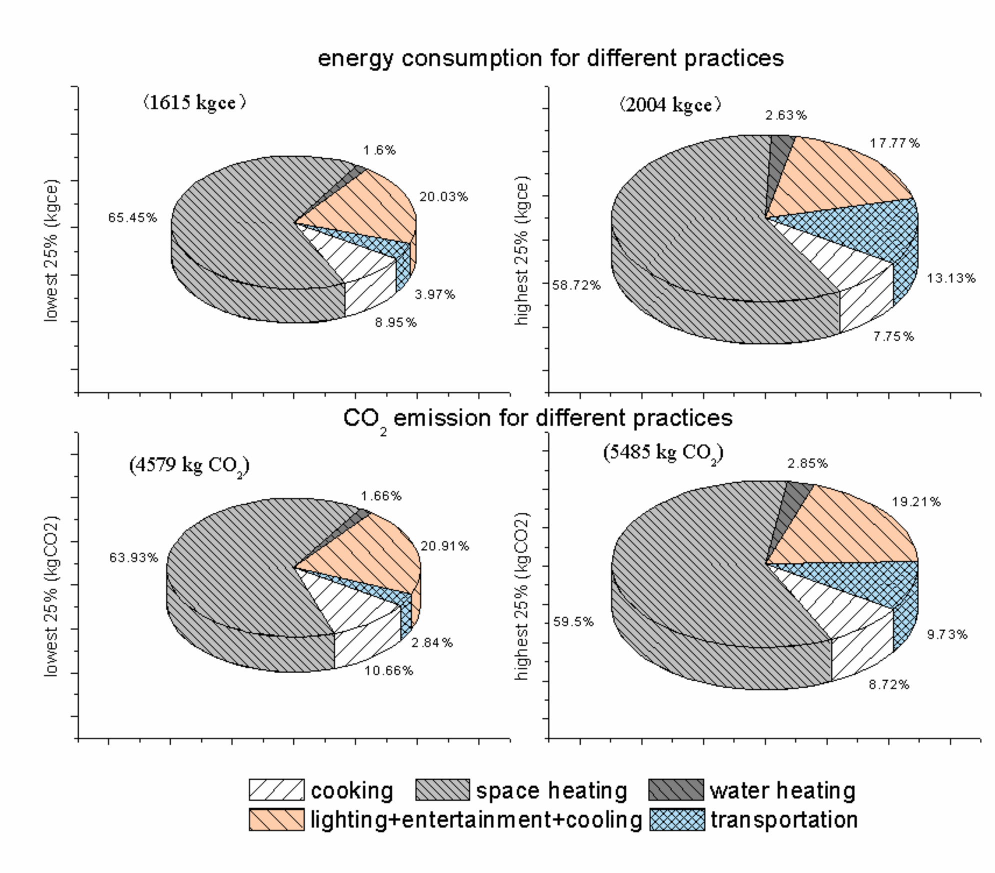

Figure 4.4 Estimated changes in the energy profiles and CO_2 emissions for low- and high income groups

4.4.2. Lifestyle-factors and their contribution to the low carbon transition

Household energy use is a highly routinized social practice, since families are inclined to use energy sources that they are familiar with or have get used to, and meanwhile they would also consider the sunk cost effects of a shift to other energy sources and devices. These factors are shared by all households and they explain why once established energy consumption practices in a certain village show robustness to change. However, in an analysis of the energy requirements for household consumption, as Vringer (2006) has revealed, even in similar socio-economic groups we witness large, unexplained differences in total energy-use. Diverse lifestyles should be considered for their different potential to contribute to a low carbon transition.

Behaviours of the households classified on the basis of income may reflect different lifestyles. We have seen clear differences to emerge between different income groups with respect to their energy consumption profile. They differ both in terms of the set of practices they embrace and with respect to the energy sources they use for these practices. As a result, the carbon profiles of the different income/lifestyle groups show marked differences. It seems that households from high income groups are likely to pursue a more convenient and comfortable lifestyle, expressed in their inclination to spend money to improve life comfort (for instance, to drive a car instead of other transportations, to have a bath more often, etc.). In contrast, people from low income groups represent a different lifestyle, characterized by an energy consumption patterns that reflects an overriding concern with meeting the basic demands of life such as space heating, cooking and so on. Against the background of this analysis, two lifestyle related questions seem particular relevant for our analysis of rural households and the low carbon transition. First, what role - if any - can be assigned to ‘environmental’ or ‘climate’ values for promoting the shift to low carbon lifestyles and patterns of energy consumption. In our survey, we have seen that economic rationality is not the only standard for people’s decision making. Rural households will not necessarily and automatically choose the cheapest energy option regardless of other factors. They choose energy options which facilitate their lives and which meet their expectations about living demands and qualities of life. Among these non-economic considerations however, environmental or climate benefits and concerns do not seem to play an important role yet for rural households. Environmental protection is a general value and an issue about which householders know from TV or from discussions with their neighbors. Environmental awareness is primarily related to industrial pollution as happening in their nearby living environment. At present however, climate change is not yet a major concern that guides household decision making on energy options. Second, existing lifestyles can play an important role in the (non-) acceptance of certain (sustainable) energy options and technologies. An illustration is provided by the (non-) uptake of biogas pools as reported in our survey. The survey results show that lots of biogas pools are wasted in one of our case villages. Ever more than one hundred households installed biogas installations but no more than ten are still in use. An important reason for this can be found in the high costs of labor and time involved in the production and use of biogas. The very limited use of this (renewable) energy source must be explained from the lifestyle preferences of local residents. Because of their increasing demand for comfort and convenience, they abandon energy practices that require a lot of work and time, whereas other, more convenient alternatives are readily available. Lifestyle preferences in our survey are also shown to prevent the uptake and use of much cleaner energy options in specific consumption practices. In the case of cooking for instance we were able to show that householders in rural Shandong who take steamed bun as their main food refuse to cook steamed bun using a LPG stove or electric cooking appliances. This is because they judge the resulting food to be distasteful. They prefer to eat that kind of food when cooked on a traditional biomass stove. This is one reason why some households reserve stoves combusting firewood or corncob for cooking[27].

4.4.3. Local energy provision systems and the low carbon transition

Consumption behaviour is embedded in social, cultural, economic and institutional infrastructures over which citizen-consumers have little influence (Barnett et al., 2011). This argument is also valid with respect to household energy consumption as discussed in this research. Rural Chinese householders can be conceptualized as passive or 'captive' consumers to a great extent. For the supply of energy sources, they are largely dependent on the local, dominant energy system, which is controlled by multiple energy suppliers (power grid enterprises, coal retailers, etc.). As a result, energy consumption could be explained to a considerable extent by focusing on some of the structural characteristics of the current systems of energy provision in rural China. Following our conceptual model as presented in Figure 4.1, we add to our discussion on consumption practices and lifestyles an analysis of the impact of the existing, local systems of energy provision in rural China. We also discuss their (potential) roles in future low carbon transitions.

In principle, rural households in the surveyed areas have access to a diverse set of energy sources, including electricity, coal, oil, LPG, biomass, solar and so on. In the Chinese context, electricity can be produced by national or private firms, with traditional or renewable resources, but all the power has to be delivered via the central grids and that is almost always the only source where rural households get their electricity from. Rural residents in Zhoucun district can purchase other commercial energy sources, such as coal, LPG, gasoline or diesel, from local retailers and the delivery is quite convenient because of the small distance from the town or city. Natural gas is provided via pipes for those living in residential buildings. In sum, it looks like a mature energy provision system which offers a range of options in terms of energy sources to be used for domestic consumption practices. Nevertheless, some problems remain regarding the characteristics of the provisioning system and its 'captive' domestic consumers.

Since residents purchase electricity from the grid directly, they cannot decide what kind of

[27] Previous studies have indicated such effects of traditional habits (or values) on lifestyles. For instance, Masera et al (2000) found that people in rural Mexico continue to use traditional biofuels even when they can afford to use modern fuels like LPG, because most people are accustomed to eating tortillas cooked on a clay baking tray over tortillas from an open wood fire.

electricity will be used. In other words, how 'clean' the electricity they use for consumption depends on the national or regional electricity infrastructures and the energy-sources used by the operators of these systems. Citizen-consumers do not decide about these matters, and they are not offered any choices for green electricity in a similar way as is the case in some OECD countries like Germany, Sweden or the Netherlands (Spaargaren and Oosterveer, 2010). Thus environmental values of residents, if any, cannot be brought to play when trying to promote a cleaner energy profile with respect to electricity use. In this context, a strategy of selling renewable electricity (e.g. from wind mills; see Han et al., 2010) next to 'conventional' electricity could be a significant step for enhancing the commitment of rural households with the low-carbon transition.

As for the nature of the coal supply, rural households report that they can purchase coal before the heating season from various local retailers, who often come to sell coal in the villages. Alternatively, residents can call them and order for the delivery of coal. This seems a quite convenient situation for households. However, in practice the householders report on unstable and uncertain levels of supply, and on problems with the quality of the coal. Price fluctuation of coal in recent years especially aggravates these problems. The residents complained that they have to pay more and more to get coal of high quality, and as a result they more often tend to buy the lower quality coal. Suppliers may change every year and they are mostly private organizations or small and temporary partnerships, which cannot ensure a long term, stable, reliable and good quality level of coal provision. For residents who buy coal with low quality, it means a larger amount of coal to be used for consumption and a higher level of carbon emissions together with other harmful substances. Based on these facts it can be argued that a well-organized market with cleaner coal provision would make an essential contribution to the low carbon transition and would be instrumental not just for the mitigation of rural CO_2 emissions but for the reduction of other harmful emissions as well.

The development of distributed renewable energy is promoted as an important strategy to promote a low carbon energy transition. Examples are the utilization of biomass and the introduction of distributed power generation using solar energy or wind power (Liu et al., 2012). These technologies, however, demand large investment for infrastructure, standardized management (see Han et al. 2008, 2009, and 2010), and public participation and acceptance (Liu et al., 2013). In one of our case villages, biogas production never materialized due to an inappropriate volume design which made it difficult to generate enough biogas. Sometimes biogas production terminated because of a lack of raw materials and as a result of insufficient technological maintenance. These biogas failures for some can be argued to result from top-down policy implementation (see also Han et al., 2008). Subsidies are provided to support the construction, while lack of technological maintenance and insufficient supervision on subsequent operation turn the project into failure.

4.5. Conclusion and policy recommendations

In this article, we estimated energy related CO_2 emissions of rural households in north China and looked into the different domestic energy use practices they originate from. We tried to specify some of the key characteristics of everyday energy practices and their CO_2 emissions to discuss the potential for a low carbon energy transition in rural China. In line with the existing literature, we showed that emissions from energy consumption of rural households tend to increase with rising levels of income and education in particular. However, to fully understand the potential for a transition towards low carbon energy use, investigating these household characteristics is not specific enough. Key elements for the low carbon transition are connected to the nature and composition of the energy profile of rural households. This profile comprises a specific number of routine energy use practices - from cooking to heating to transports - and can be shown to generate either high or low carbon emission levels, depending from the energy sources used and the technical devices employed in the practice. Having opened up in this way the ‘black box’ of rural domestic energy consumption we were able to sketch some innovative pathways towards a low carbon future for households in rural China. Next to the use of different energy sources and energy saving technologies, also a reconfiguration of the set of energy consumption practices and the emergence of new practices were shown to contribute to the low carbon transition. Shifts in domestic patterns of energy use, so we argued, are more feasible to happen when initiated and actively supported by systems of energy provision and when not running counter to the lifestyle-preferences and established routines of rural householders. These are the conclusions with respect to the central question regarding the nature of energy consumption in rural households and their potential contribution to a low carbon future. We finalize with some more specific conclusions and recommendations, looking into measures for distinguished practices, technologies and providers.

Space heating (in the northern area) we found to be the largest CO_2 emission source among the various energy practices. In the Zhoucun district the huge energy demand for winter heating was a major cause of high levels of CO_2 emissions. To mitigate carbon emissions from space heating, improving the efficiency of coal stoves and the quality of the coal used can be expected to have a significant impact, next to the promotion of central heating systems. In addition, so called Demand Side Management (DSM) programs can be developed to help reduce the energy demand for space heating. Such DSM programs can include insulation programs and the building of energy efficient houses, next to information campaigns inviting householders to shift to low carbon energy use practices.

The differences in energy consumption between income groups that we showed to exist imply that the increased purchase of some modern products (such as a car, an air conditioner and a computer) by the relatively 'rich' rural households might be expected to occur in the next future. This will bring along an increase of carbon emissions from practices such as entertainment and transportation. Since these products are well marketed, some market oriented policies to ensure and enhance the provision of climate friendly variants of these products and technologies could be considered an effective measure to mitigate carbon emissions from rural domestic practices. For instance when the promotion of energy efficient appliances would be included in policies directed at rural areas it could contribute to the mitigation of rural carbon emissions. This could take the form of lowering prices with the help of market based instruments or promoting the substitution of less clean fuels like coal with other energy sources. When giving support to householders who buy a more energy efficient car for example, this would help mitigate emissions from rural transportation practices.

Our study showed that electricity is already widely used for a diverse range of domestic consumption practices in rural China. Since electricity represents a relatively clean source of energy and since most households have a good connection with the power grids in these areas, a national strategy to improve the share of clean and renewable power generation would be instrumental for mitigating carbon emissions from rural households. It goes without saying that the further introduction and development of renewable energy sources in rural areas has an important and strategic role to play in this respect.

Besides the endowment of households with cleaner energy resources by local providers, our analysis showed that also non-technical factors need to be considered for the low carbon energy transition. For instance, along with rural economic development, people will develop a taste or even a need for a higher quality of life in terms of higher levels of comfort and convenience. One of the lessons to be learned is that the further development and use of low carbon energy sources and technologies can be expected to be the more successful when local conditions and prerequisites are taken into account. Low carbon energy options should fit the (income) characteristics and lifestyles of rural householders in order to effectively combine rural development with the aim of mitigating climate change.

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Chapter 5. Low carbon rural housing provision in China: participation and decision making[28]

Abstract

Under the national strategy of ‘building a new socialist countryside’, concentrated rural housing is increasing in some rural regions in China. In this research we use three case studies to analyze decision making on concentrated rural housing and the potential for future low carbon rural housing. The empirical results show that concentrated rural housing can improve both the energy efficiency of houses and the living conditions of households, compared to traditional stand-alone modes of housing. Providers are the major decision makers with regard to the kind of materials, technologies and energy networks applied in rural housing development. Local governments, private property developers and local (energy) authorities in principle have the power to select and apply low carbon alternatives. The involvement of Chinese householders in concentrated housing project turns out to be low or non-existent. The introduction of market incentives, stricter building regulations, better decision making processes and communication with householders are relevant social factors for improving low carbon housing provision in rural China.

Key words:

Rural China, low carbon housing, decision making models, participation, energy infrastructures

5.1. Introduction

Despite its scarce attention so far in policy and sciences, rural domestic energy consumption is an important factor in climate change mitigation and energy security in China (Liu et al., 2012). Rural housing is not only of fundamental importance for rural citizens but also a key element determining greenhouse gas emissions. The style of rural housing strongly affects household energy consumption and the options to reduce carbon emissions. On the one

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hand, the connection to regional or local energy infrastructures determines to a major extent the energy options of rural households for space heating, cooking, water heating, lighting and so on. On the other hand, the way the houses are built - for instance in terms of materials applied, energy related technologies adopted and energy infrastructures put in place - directly affects domestic energy demand. The type of buildings and the infrastructures connected to them do lock-in energy consumption (practices) of householders to a considerable extent. For example Sahakian (2011) showed that the long-term intensive energy use of houses in Metro Manila, Philippines, was rooted in the no or low passive ventilation constructions that were applied when mimicking Western architectural styles.

Under the national strategy ‘building a new socialist countryside’, rural housing provision (and renovation) in China has diversified in recent years. Especially, since land scarcity became more prominent in rural China, concentrated housing projects intensified. It is unknown, however, whether, to what extent and how low carbon requirements are being considered during concentrated rural housing provision and renovation. With the building sector being identified as one of the largest GHG emission sources (Colombier and Li, 2012), low carbon rural housing has become important to tackle climate change. Against this background, it is important to know who decides on the housing provision and what low carbon alternatives are being applied. It is often argued that communication and user participation are crucial for effective sustainable housing projects, since users have to accept and incorporate low carbon alternatives into their everyday housing situation (Lizarralde and Massyn, 2008). User or community participation is usually associated with so-called bottom-up approaches (EI-Masri and Kellett, 2001) and ‘grass root’ development. This is contrasted with top-down approaches, where housing is provided and decided by centralized actors with the help of command-and-control rules. While promoting low carbon housing never follows only a bottom-up or a top-down approach, the specific combination of approaches and the actor constellation vary considerably under different circumstances and in different countries.

In China, rural housing is related to aspects of migration, employment, land use, energy consumption and natural environment (Long et al., 2010). Concentrated rural housing projects typically relate to migration, the need to find the right balance between construction land and agricultural land, and more than incidentally to controversies around land use changes (Long et al., 2009) and equity issues (Wainwright, 2012). However, issues of land use changes, enforced migration and equity issues are not at the centre of our analysis. We look into decision making, communication and participation around introducing low carbon alternatives into rural housing projects. Three different models of housing decision making in rural China are distinguished and analyzed on the actors and potential to introduce low carbon energy options. The next section introduces the background of rural housing provision in China, followed by section three that provides our analytical framework and methodology. Section four elaborates and compares the empirical results from our three case studies. The final section discusses the results and concludes on future policies for a rural low carbon transition.

5.2. The background of rural housing in China

Houses are basic fixed assets and a major family property for many rural households. For a long time, rural housing provision fell behind urban housing provision. However, since China's reform and opening-up, construction of rural housing has changed dramatically. As shown in Figure 5.1, the living space per capita of rural residents increased from 8.1 m^2 in 1978 to 34.1 m^2 in 2010 and rural housing quality also improved and diversified (Li, 2011). In 2010, 70% of new constructed rural houses were with reinforced concrete structure versus 26.2% with masonry-timber structure. This followed from a change in China's rural housing policy. In the 1980s, with a national demand to ensure or increase living space of rural residents, housing policy focused on the quantity of housing provision, while more recently attention shifted to housing quality. Especially in the context of global climate change mitigation, energy efficiency of construction works and houses has become a focal point in recent years. Trial energy technology policy of rural housing has been established, stimulating the adoption of energy-efficient technologies regarding building walls, windows and space heating systems[29]. Renewable energy technologies in rural construction have also received widespread attention in China (Zhu and Zhang, 2011).

[29] The Ministry of Housing and Urban-Rural Development in China. Rural housing construction and technology policy. 2011.9. available at: http://www.mohurd.gov.cn/zcfg/jsbwj_0/jsbwjjskj/201109/W020110919014847.doc

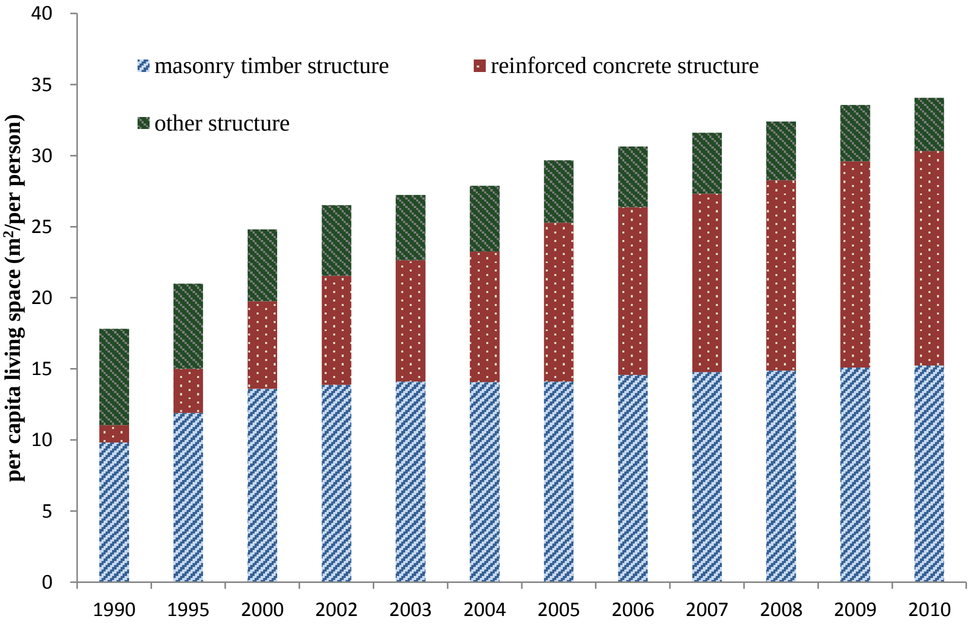

Figure 5.1 Per capita living space of rural residents and housing structure in China (Data source: China Statistical Yearbook, 2011)

Rural housing in post-1949 China shows some unique and special characteristics. The principle 'one household one house' was set in the 1950s and has not altered basically (Liu, 2008). Rural residential land is owned by the village collective, and every rural household is eligible to apply for one piece of residential land for free (practices may vary between regions). Rural households could build their own houses, but at the same time these houses are not tradable in the market and transfer of rural residential property is legally confined within the village. Thus rural housing differs from the rapid privatization of urban residential property (Wang and Wang, 2012). In all, rural households own the house property and have been given responsibility for financing, construction, management, maintenance and use of their houses (Li, 2011). Current policy empowers rural households with the rights of decision making, which however leads to several problems.

Recently, problems in rural housing construction have gradually emerged. According to the Ministry of Housing and Urban-Rural Development, one commonly finds irregular and reckless construction not following the construction plan, lack of 'scientific' design and simple reproduction of urban housing design, absence of inspection and supervision on materials and construction process, and serious waste of land, materials, funds and energy[29]. Hence, the quality, functions and energy efficiency performance of rural housing cannot be guaranteed. In northern China, most rural houses are stand-alone, and brick walls have replaced mud walls in the past few decades. The thermal resistance of a brick wall is only 1/3~1/2 of a mud wall, and 1/3 of that required in the urban building standard (Zhang et al., 2011_a). Home-made central heating and Chinese kang[30] are commonly used for space heating in northern China, of which the (device) heating efficiency[31] is found to be only 40% (RCBEE, 2012). Previous research (Liu et al., 2013) proved that space heating consumed the largest share of rural household energy in northern regions, which is closely linked to low energy efficiency and poor thermal performance of stand-alone rural houses.

In recent years, an innovation within the current land quota system was introduced: ‘Linkage between Urban-land Taking and Rural-land Giving’ (LUTRG). Since early 2009, the central government recommended its nationwide implementation. With the LUTRG, governments of rapidly expanding cities are allowed to increase their conversion of farmland into legal urban development land above the limits set by annual quota. ‘Urban-land taking’ in LUTRG refers to urban expansion occupying farmland, and ‘rural-land giving’ refers to the government reclaiming the same amount of farmland by converting rural residential (or other construction) land and more intensively and efficiently using the remaining part of the rural construction land. The purpose is not to reduce the amount of farmland (e.g. Anderson, 2010).

In this context, rural housing policy emphasizes more centralized and concentrated living, and the construction of small towns or central villages.[32] Along with “rural urbanization”, more and more multi-story buildings are constructed in rural areas, which have been criticized as imitations and simplifications of urban buildings and having inferior thermal performance and higher energy consumption. But provision of new houses may also improve the quality of life of rural residents, and energy efficiency and carbon emissions associated with new houses can be taken into account in new rural housing provision. Against this background we investigate decision making and participation in concentrated housing projects in rural China, focusing on the issue of low carbon housing in particular.

[30] See footnote 7 in chapter 2.
[31] The ratio of effectively used heat by the equipment to total heat supply.
[32] The Ministry of Land and Resources. Notice on further improving the rural homestead management system to effectively safeguard the rights and interests of farmers. Available at: http://www.mlr.gov.cn/zwgk/zytz/201003/t20100303_138571.htm

5.3. Analytical framework and methodology

5.3.1. Analytical framework

This research focuses on the actors and agencies involved in the decision making processes with regard to (low carbon) rural housing. We start with outlining the key dimensions in low carbon rural housing, subsequently discuss the key actors involved, then present three different modalities of decision making used in developing housing projects, and finally present the low carbon alternatives that are object of decision making.

Figure 5.2 summarizes the main dimensions involved in low carbon rural housing. The carbon profile of a household is determined by three key elements: 1) the construction of the house, using (low carbon) materials, technologies as well as 'internal' or house-bound energy infrastructures such as a heating installation or a solar-water heater; 2) the energy infrastructures at neighborhood, community or regional level to which the houses are connected, varying from biogas installations, windmill parks to coal fired power plants or natural gas grids; 3) the energy consumption practices or routines enacted by residents when dwelling their homes, such as heating and cooling the rooms, cooking and showering. These three main elements determine the carbon profile and performance of houses and households.

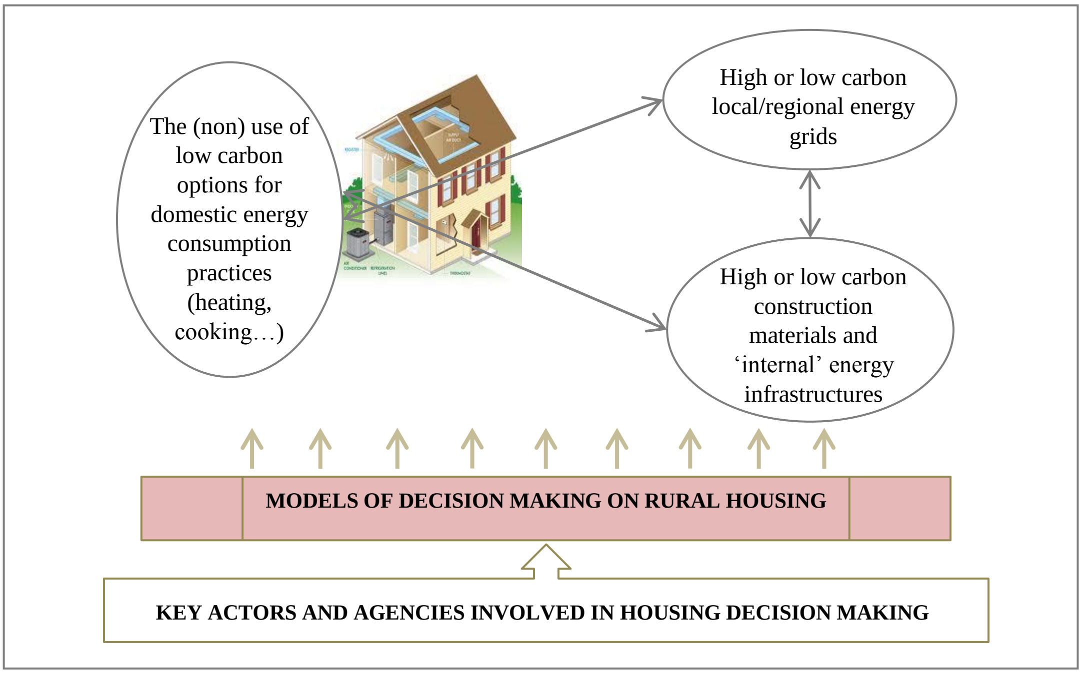

Figure 5.2 Three dimensions for studying low carbon housing projects

Key actors involved in decision making

A variety of actors are involved in decision making processes that determine the carbon performances of rural households in China. The state or public sector agencies have traditionally been strong if not dominant actors in housing development and provision (Keivani and Werna, 2001; Doherty, 2004; Allen, 2006; Özdemir, 2011). Some argue that over the past decades, the national government has failed to achieve the desired results in the housing sector (Adegun and Taiwo, 2011). Especially since the 1980s, a worldwide discussion emerged on the need to reduce the role of governments in the direct provision of houses, arguing for an expansion of reliance on the private market in housing provision (Israel, 1990; World Bank, 1988). As a result of this, the private sector has become an important actor in rural housing decision making, often through increased collaboration between the public and private sector (Tsenkova and Witwer, 2011; Madden, 2011). China has undergone similar transitions. A series of reforms on housing and land markets in urban areas made millions of urban residents homeowners through either privatization of existing public housing stocks or via purchases on the commercial housing market (Wang & Murie, 1996). The traditional public housing system was gradually phased out from the urban housing market.

Besides these two actors, householders who dwell their homes make use of the infrastructures and technologies to perform their everyday energy consumption routines. Some argue that householder behaviour is crucial for determining the final climate performance of housing projects (Lizarralde and Massyn, 2008; Hall and Hickman, 2011). When householders do not know, understand or accept the low carbon energy options made available, low carbon alternatives provide sub-optimal results. Hence, some argue that bottom-up processes, 'grassroots innovation' and participation of householders is a key factor to successful low carbon housing projects (Seyfang, 2010).

Three models of housing provision

Housing provision involves a complex process which can be specified for three different phases: 1) planning and initial project decision making; 2) design and construction of the project; 3) use and maintenance of the developed houses and infrastructures. Decisions on development and use of housing technologies and infrastructures are often not taken at the same stage by the same set of decision makers. At the different stages different actors play leading roles, and their roles and powers are determined by the kind of decision making model used.

At least three commonly used models can be identified in developing countries and have been put into practice in rural China: a) *state or government led housing provision*, within which the building program is initiated and controlled directly by the central or local government (Keivani and Werma, 2001; Doherty, 2004); b) *joint venture schemes between public and private sectors*, in which public authorities usually provide suitable land and tax incentives, and private firms finance and build housing units, in exchange for being able to sell an agreed part of the projects on the open market and offer the rest to low income households at agreed prices (Keivani and Werma, 2001; Murillo, 2001; Madden, 2011); c) *private sector housing provision*, which may take many forms like individual (owner-led) house building, property developer led housing development, or housing development through the cooperation between developer and house or land owners (Tsenkova and Witwer, 2011). This research aims to examine the decision making process within these three distinguished models of rural housing provision.

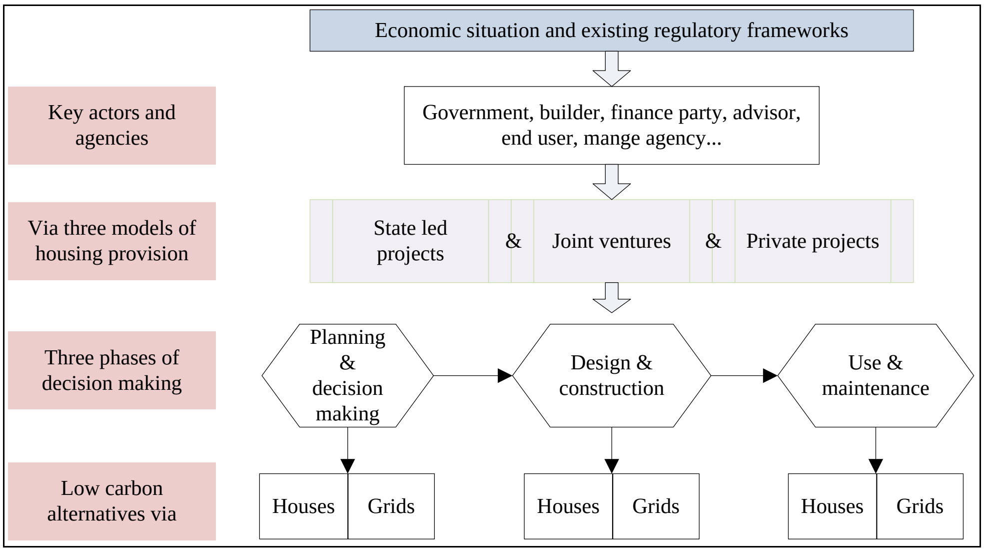

Figure 5.3 A framework for studying decision making on low carbon alternatives for rural Chinese households

Figure 5.3 gives an analytical framework that specifies the different actors, the models of decision making, the phases in the decision making processes and the low-carbon alternatives that can be object of decision making. For all decision making processes background factors, such as economic feasibility and relevant regulations, to some extent affect decision-making. This model helps to analyze at what time and by whom low carbon alternatives for rural housing are being considered and decided upon. Next we present the low carbon options most commonly discussed and considered.

Low carbon alternatives as objects of decision making

Low carbon alternatives for housing are widely discussed as 'green elements', 'green technologies', 'green strategies' or 'low carbon systems'. Previous studies addressed various low carbon technologies, focusing either on house-related options (including materials, monitoring and feed-back systems, internal energy infrastructures, etc.) or grid-related systems. For example, a so called green roof system is identified by Nelms et al (2007) as an effective means to reduce energy consumption, by improving insulation and reducing space-conditioning requirements of buildings. Renewable energy applications prevail in the literature, such as distributed generating systems (with PV, wind power, biomass) connected to rural houses in China (Liu et al., 2011; Han et al., 2008) or ground source heat pump technology (Doherty et al., 2004). Energy efficiency monitoring arrangements are identified by Bell and Lowe (2000) as low carbon technologies in UK housing projects. Table 5.1 lists a wide variety of low carbon alternatives in housing, based on previous literatures and relevant policy standards. These low carbon alternatives formed a checklist that was applied in interviews and analysis. Although the list is not exhaustive or complete, the low carbon elements represents alternatives that could realistically be considered and applied in Chinese rural housing projects. Since the emphasis is on decision makers in provisioning systems, (behavioural and technical) alternatives for consumption practices were only indirectly considered, for example discussed in relation with the need for providers to consider (active) communication with and participation of end-users as part of decision making procedures.

Table 5.1 House and grid related low carbon elements in rural housing development

Number	Low carbon alternatives	Key references or policy standards
House related:		
L1	Considering environmental impact when selecting project site	United Nation Environmental Program(2005)
L2	Optimizing building orientation	Glicksman et al (2001)
L3	Application of green roof technology	Nelms et al (2007)
L4	Thermal insulation of walls and roof	Zhang et al (2012)
L5	Application of low-E insulation window technology	Kirby and Williams (1991)
L6	Use of green wall materials	UNEP(2003)
L7	Ample ventilation for pollutant and thermal control	U.S Department of Energy (2009)

L8	Energy efficient lighting system	
L9	Application of (internal) energy efficient space heating system	
L10	Application of (self-contained) solar water heating system (or PV)	Liu et al (2011); Han et al (2010)
L11	Application of green technology monitor and maintenance system	U.S Department of Energy (2009)
Grid related:		
L12	Application of natural gas for heating and cooking	
L13	Application of ground source heat pump technology	Doherty et al (2004)
L14	Central space heating system	
L15	Central water heating system using solar energy	Liu et al (2011)
L16	Combined heat and power system	Zhang et al (2012)
L17	Connected with distributed renewable electricity generation (wind power, bio-fuel, solar energy…)	Liu et al (2011); Han et al (2008)

This analytical framework on decision making on low carbon alternatives in rural housing development projects in China results in three main research questions that organized our empirical research:

- Who are the main actors - operating in the different phases of the building project - responsible for decision-making on the (non) application of low carbon alternatives for rural housing in China?
- Is there a difference in actors and their decisions between the three different models of rural housing provision?
- Which recommendations can be derived to improve decision making processes on low carbon housing provision in rural China?

5.3.2. Methodology: selection of case study areas and data collection

Previous research emphasized the important contribution of space heating to greenhouse gas emissions in Northern China (Liu et al., 2013). Hence, this research focuses on rural housing projects in northern areas. Shandong province and Inner Mongolia autonomous region are selected to conduct case studies. Different case areas (towns) for three modes of housing provision are identified via literature investigation, including reviews on media, governmental reports and academic studies.

Shandong's rural economy, including rural housing, has developed significantly over the last three decades. In 2010, the annual per capita net income of rural residents in Shandong was 6837 Yuan, around 32 times that in 1980, and 15.5% higher than the national average[33]. Rapid rural economic development led to a dramatic increase of rural housing demand. Previous research (Guo and Peng, 2011) showed that expenditures of rural residents on housing in Shandong rose at an annual average rate of 30% from 1995 to 2008. Local government support contributed to rural housing in Shandong by investing 60 billion Yuan on rural housing construction and rehabilitation between 2009 and 2011. Over twelve thousand villages were rebuilt, concentrated rural houses were provided for 3.2 million households, and housing conditions for 20% of provincial rural residents improved[34]. The pattern of rural housing provision (usually together with village rebuilding) in Shandong was highly praised and taken as references by other provinces. Two case studies of 'rebuilding villages within or beside the city'[35] were carried out in the municipalities of Qingdao and Weifang, respectively representing the models of 'state led or governmental housing provision' and 'joint venture scheme'.

As a comparison, Inner Mongolia was selected as another case study region, characterized by a relatively weak economic condition but higher levels of land availability. Rural housing construction in Inner Mongolia is not as popular as it is in Shandong, caused by a lower level of economic development. In 2010 the annual per capita net income of rural residents in Inner Mongolia was 5530 Yuan, 6.6% below the national average[36]. Rural housing has not attracted as much attention as in Shandong and only under a nation-wide housing policy. Dilapidated housing rehabilitation is carried out, especially in pasturing areas. Local governments are hardly involved in rural housing provision nor take a leading role in initiating or financing such projects. Hence, prominent are cases of new housing delivery being governed by local property developers, representing the 'private provision' model. Two villages of Chifeng municipality were chosen for investigating this mode in more detail.

In total five towns were identified, representing the three typical models of concentrated rural housing provisioning. Semi-structured interviews (see Appendix III the checklist for interview) were used as the main data collection method for these five cases, using a specific checklist for the different categories of interviewees. The selection of key actors to be interviewed was enacted in a top-down way, starting with interviewees at the town level in

[33] Data source: Shandong economic and social development statistics bulletin 2010.
[34] "Large-scale rural housing construction in Shandong has boosted domestic demand and created employment." Available at: http://native.cnr.cn/city/201206/t20120627_510035907.html
[35] http://news.bandao.cn/news_html/201001/20100125/news_20100125_898020.shtml
[36] Inner Mongolia economic and social development statistics bulletin 2010

each area, then following up with interviewees at the village (also property developer) level, and finally organizing interviews at the community and household level. Interviews with officials from the town government (two interviewees in each town) helped us to identify the housing situation in general and to make a selection of typical villages. Usually members of village committees and also property developers (three to four interviewed in each case) provided specific information about the housing project, acting as our major sources of information. A number of rural households (five to seven) in each case village were randomly selected for an interview.

5.4. Empirical case study results

5.4.1. State or government led housing provision

Xijiazhuang village, located in Weicheng district in Weifang, Shandong, is an example of state led housing provision. There are around 400 households in this village. They have moved into their newly-built houses since the year 2011. The new housing project was accomplished under the program 'rebuilding an old village', initiated by the village committee as a response to a call from higher-level governments. Multiple-storied buildings were built to replace traditional stand-alone (single-story) rural houses. Since this village is located nearby the central district of Weifang and zoned as part of an economic development area, part of the village collective land has been converted to urban land and reserved as development area. In return the village received a compensation fund that financed and promoted the development of new rural housing (see the LUTRG policy discussed above).

Figure 5.4 describes the process of housing provision in this case. Before starting the program of rebuilding an old village, the village committee first had to obtain permission of the superior-level government. Besides, approval of local villagers is compulsory for implementing such a program. The village committee should keep villagers informed and help them to understand the program via introductory workshops or other approaches. A formal questionnaire was sent to each household with details in terms of the land transfer and the rules of exchanging new housing property for an old stand-alone house. In this case, the village committee financed this program with the land compensation fund supplemented by bank loan. A property developer or construction company was selected via an open tender, and took charge of the construction process. During the construction, relevant rules and standards had to be obeyed. In particular, construction works had to be verified and approved by the municipal building and construction bureau, and the fundamental building design had to be carried out by qualified municipal planning and designing institutes. Once completed, the houses were distributed first to villagers according to the agreements reached; extra houses were sold or rented out as village collective properties.

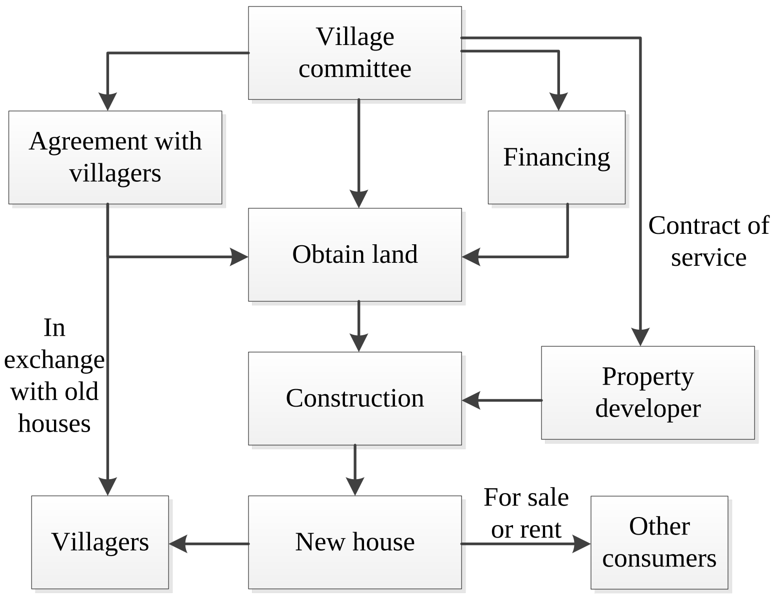

Figure 5.4 Village-dominated housing development in Xijiazhuang village

Energy-related housing aspects were not deliberately considered in the case of Xijiazhuang village, a few (house- and grid-related) low carbon options were adopted in the new houses (see Table 5.2). The table lists the applied low carbon alternatives associated with each energy use practice and links them to different phases in the process of housing development with its typical decision makers. Compared with energy options when living in the traditional stand-alone houses, the cooking, space heating, water heating and lighting energy use practices are fundamentally different.

Table 5.2 Energy options and decision making in government housing provision, Xijiazhuang village

Energy use practice	Related low carbon alternatives	Options after rebuilding	Process phase of decision	Major decision maker	Energy options stand-alone house (for comparison)
Cooking	L12	Natural gas	Phase 1	Village committee,	LPG, electricity, biomass

			Phase 3	householders	
Space heating	L2	Optimizing the building orientation	Phase 2	Property developer	May be considered by households
	L4	Adoption of insulation materials for walls and roofs	Phase 2	Property developer	Not considered
	L6	Adoption of green wall material	Phase 2	Property developer	Not considered
	L9	Radiant under-floor heating	Phase 2	Village committee	Household coal stoves and bed heating (kang)
	L14	Central heating with coal	Phase 1	Village committee	
Water heating	L10	Solar water heater	Phase 2,3	Village committee	Coal or biomass stoves
Lighting	L8	Energy-saving lights	Phase 3	Households	Energy-saving light and common lights

In the planning phase, the village committee decided on the development of the housing program and planned the type of energy grid or infrastructure to which the new buildings were to be connected. In this case, new buildings were connected to a natural gas grid and a central space heating system (supplied by a nearby heating power company) was installed, instead of using liquefied petroleum gas for cooking and household coal stoves for space heating. These decisions took into consideration the local conditions of the economy, resources and infrastructure, but communication with and participation of households were not part of decision making. In governmental housing provision, it seems logical that the provider - the village committee in this case - plays a key role in decision making on the adoption of low carbon alternatives, especially during the planning and decision making phase.

The property developer was involved in decision making during the designing and constructing phase. As the housing program was developed after 2008, the Civil building energy conservation regulations released in 2008 had to be executed[37]. Following these regulations, thermal insulation of walls and roof, and new wall materials were adopted. In addition, the building orientation was considered by the property developer in order to better make use of the available passive solar power and natural lighting. The village collective also influenced the design and construction process. For example, an indoor under-floor heating

[37] "The Civil Building Energy Conservation Regulations". Available at: http://www.gov.cn/zwgk/2008-08/07/content_1067038.htm.

system was required and the installation of solar water heaters was uniformly designed[38]. But in general the property developer made the major decisions in this phase, and thus determined the extent to which low carbon technologies were put into use.

During the use and maintenance phase, households that moved into their apartments could decide on energy option use for daily practices. But their choices were evidently limited by the available energy infrastructure and grid connections. Interviews with five randomly selected households give more insight into their energy use practices. They all accepted all energy options that were provided within their new apartments. Energy-saving lighting was used by all households. Although energy expenditures had increased, all interviewed households were positive about the improvement of their living conditions. The village collective is responsible for the management and maintenance of the new buildings and for the community services, but is not allowed to intervene in the energy use behaviour of the tenants. Meters for measuring the use of water, electricity and natural gas have been installed in each house, allowing occupants to monitor their daily energy consumption.

5.4.2. Public-private joint venture scheme of housing provision

Using two cases public-private joint arrangements of housing provision were examined. Xitian village, located in Chengyang district of Qingdao, Shandong, recently established a community with 28 residential buildings with houses for all 300 village households as well as some people from outside. The community was built under the program of ‘rebuilding an old village’ and ‘building a new socialist countryside’. Xiyuanzhuang village, located in Jimo County, Qingdao, Shandong, was rebuilt in the same way, relocating all 700 households into the newly-built community since 2006.

The two villages have undergone a similar process of rural housing development. As shown in Figure 5.5, the program started from a cooperation agreement between the village committee and a real estate developer, who negotiated the rules of land transfer and the relocation of households after their houses would be demolished. The property developer obtained the construction land at a low price as it would be responsible for housing provision for the relocated households. Before starting the formal cooperation, the village committee had to acquire approval from the households, similar to the first model. Introductory

[38] The provincial government of Shandong released 'Policies and measures on promoting dissemination and application of solar thermal systems' in 2009, requiring solar thermal systems to be planned, designed and implemented together with building construction. This is applicable for any new building in cities and towns above county level. (http://www.nengyuan.net/200911/05-458166.html)

workshops and questionnaire surveys were applied until all households were willing to sign the agreements for housing demolition and for exchanging their houses for new apartments. The property developer took charge of the financing and construction of the new buildings. As with the first model, the construction works had to be verified and approved by the municipal building and construction bureau, and the building design had to be completed by qualified municipal planning and designing institutes. Houses were classified into two categories: village collective property distributed to the relocated households; and commercial residential buildings sold or rented to people from outside the village. In similar other cases the property developer also developed commercial buildings to be sold or rented to factories or companies, depending on the agreements with the village collective.

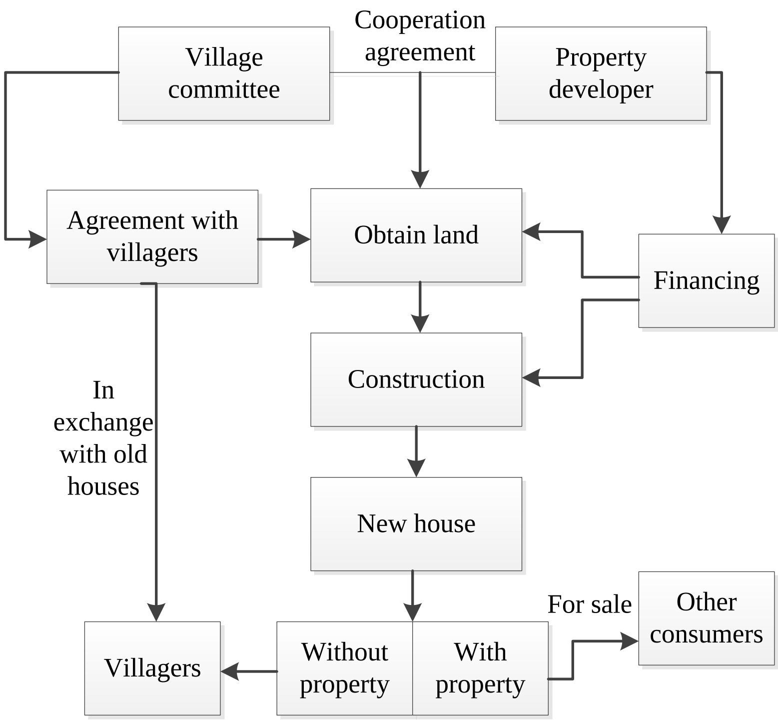

Figure 5.5 Joint public-private housing development in Xitian village and Xiyuanzhuang village

Besides a comparable economic and natural resource background, the two villages also share similar energy-related options. Although the property developer was in charge of the construction works, the village collective participated in discussions and decision making about infrastructure services and connections to the grids. An overview of the energy options and the decision makers in each phase in the two villages is provided in Table 5.3. Grid-related energy options were decided by the village collective during the first planning phase.

The buildings in the two villages were both connected to the natural gas grid, and the central heating systems were provided by heating power companies from Chengyang district and Jimo County, respectively. Other low carbon alternatives were decided by the property developer during the design and construction phase. Buildings developed after 2008 followed the Civil building energy conservation regulations of 2008, and therefore adopted thermal insulation and new materials for the walls and roof. Optimizing the building orientation was followed as well. The indoor heating systems constructed in the new buildings differed between the two villages, following different preferences of the two property developers. In Xitian village heating pipes were placed under the floor for each house, while in Xiyuanzhuang village common heating radiators were installed. The village committees were also involved in the decision making in this phase and proposed, for instance, a uniform application of solar water heaters. Again, no participation of house users was considered during decision making. The management and maintenance of the energy infrastructure in the new communities is the responsibility of the village collective for houses of relocated households, and the responsibility of the property developer for those with commercial properties.

It should be noted that there is still room for more low carbon applications. Within a public-private joint venture scheme, grid-related energy options depend on the common decision of the public sector - i.e. the village committee - during the planning process. The choice between different house-related (internal) energy technologies, on the other hand, mainly depends on the property developer, and is made during the design and construction phase.

Table 5.3 Energy options and decision making in public-private joint housing provision, Xitian village and Xiyuanzhuang village

Energy use practices	Related low carbon alternatives	Options after rebuilding	Process phase of decision	Major decision maker	Energy options stand-alone house (for comparison)
Cooking	L12	Natural gas	Phase 1 Phase 3	Village committee, households	LPG, electricity, biomass
Space heating	L2	Optimizing the building orientation	Phase 2	Property developer	Might be considered by households
	L4	Adoption of insulation materials for walls and roofs	Phase 2	Property developer	Not considered

	L6	Adoption of green wall material	Phase 2	Property developer	Not considered
	L9	Radiant (under-floor) heating	Phase 2	Property developer	Household coal stoves and bed heating (coal)
	L14	Central heating based on coal	Phase 1	Village committee	
Water heating	L10	Solar water heater	Phase 2,3	Village committee	Coal or biomass stoves
Lighting	L8	Energy-saving lights	Phase 3	Households	Energy-saving lights and common lights

In these cases, not all households comply with the energy options provided. In Xiyuanzhuang village, some households changed the indoor heating system into a radiant under-floor heating system in order to gain more room space and obtain better heating effects (according to interviewed householders). Meters for measuring water, electricity and natural gas were also installed, enabling tenants to monitor their domestic energy expenditures.

5.4.3. Private sector housing provision

This section introduces two private sector housing provision projects in Chifeng municipality, located in the southeast of Inner Mongolia. The two case villages, Chutoulang and Guanjiaying, are both located in Songshan district, not far from the central city. Limited urban expansion and a strong reliance on agriculture make concentrated rural housing uncommon in this district. Non-agricultural employment in the city triggered a growing housing demand in surrounding areas, including some nearby villages. Since the area is rich in molybdenum minerals, multiple factories with new employment opportunities create new needs for housing provision nearby.

Different from the two models above, rural housing provision in this model was a commercial development, initiated by profit-oriented private property developers. In the Guanjiaying housing project, the property developer obtained land from the village committee via a competitive tender (right-hand side Figure 5.6). This is possible when unused collective village land is available. Another possibility (Figure 5.6 left-hand side) is that a property developer negotiates with local residents about the exchange of new houses for old houses. If an agreement is reached, the property developer acquires the right to develop construction land after demolition of the old houses. In the former mode, the property developer sells or rents houses out for profit. In the latter case, the property developer first needs to relocate the households whose houses will be demolished; and he can sell the extra houses only after relocation has taken place. Both modes can co-exist within one project, which was the case with the Chutoulang housing program.

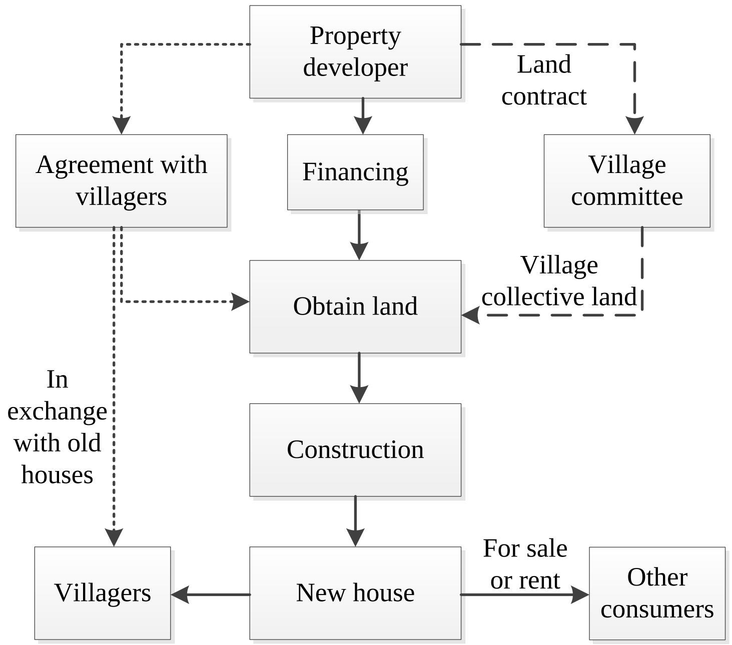

Figure 5.6 Private sector housing development in Chutoulang village and Guanjiaying village

The property developers were in charge of financing and construction in the two villages. But again construction work and fundamental building design had to be verified by stipulated institutes. During these initial processes, neither town governments nor village committees were involved in decision making about construction details, but they did provide energy (and water) related infrastructures. None of the households were involved in the decision making processes.

Compared with stand-alone houses, living in concentrated buildings has dramatically changed the practices of household daily energy use. As shown in Table 5.4, the property developer obviously dominates decision making during planning and construction phases. Grid and infrastructure connections with new houses, for example the energy network for space heating, are usually discussed during the first phase. Since the two case-study villages were not connected with any heat supply company, the developers established independent heating systems, containing heating boilers, a supply network and connections with common indoor radiant heating systems. Among the 30 buildings that were developed in Chutoulang village, two buildings adopted ground source heat pump technology for space heating, and combined it with indoor radiant under-floor heating systems. It was initiated as a pilot project by one of the property developers, for which they would be eligible for government subsidies after putting it into operation. Space heating with a ground source heat pump costs 25 Yuan per square meter, while using a common heating boiler system costs more than 30 Yuan per square meter. Solar water heaters were also popular in these new-built buildings. Thermal insulation and new materials for walls and roof were applied as required. Natural gas for cooking was not available in these two villages. Instead, households could choose liquefied petroleum gas or/and electricity for cooking, replacing the use of traditional biomass in stand-alone rural houses.

In summary, given the constraints posed by relevant building regulations and norms, choices of technology, materials and energy networks in the private sector based mode of housing provision are mainly made by property developers. Local resource and economic restrictions limit the range of choices. In this case, subsidies for new technologies or products triggered the interests of private sector in practicing new technologies and to promote applications of low carbon alternatives.

Table 5.4 Energy options and decision making in private sector housing provision, Chutoulang village and Guanjiaying village

Energy use practices	**Related low carbon alternatives**	**Options after rebuilding**	**Process phase of decision**	**Major decision maker**	**Energy options stand-alone house (for comparison)**
Cooking	-	LPG, electricity	Phase 3	Households	Coal, electricity, biomass
Space heating	L2	Optimizing the building orientation	Phase 2	Property developer	Might be considered by households
	L4	Adoption of insulation materials for walls and roofs	Phase 2	Property developer	Not considered
	L9	Radiant (under-floor) heating	Phase 2	Property developer	Household coal stoves and bed heating (kang)
	L14	Small central heating system with coal	Phase 1	Property developer	
	L13	Ground source pump heating	Phase 1	Property developer	

Water heating	L10	Solar water heater	Phase 2,3	Property developer, households	Coal or biomass stoves
Lighting	L8	Energy-saving lights	Phase 3	Households	Energy-saving lights and common lights

The management and maintenance of energy infrastructure is the responsibility of the property developers, but they do not intervene with the energy use choices of the occupants. Meters for measuring water and electricity have been installed for each household. Interviewed households indicated that their energy expenditures have increased, but that their living conditions have also improved. Those still engaged in agricultural production, however, mentioned some inconvenience caused by lack of space for agricultural equipment in the new buildings.

5.4.4. Comparison of the case studies

The low carbon decision making process turns out to be closely linked with the mode of housing provision. The degree of involvement of different actors and their impact on the application of low carbon alternatives differ between the different models of housing provision (Table 5.5). Housing providers obviously are major decision makers, especially during the first two phases of housing development. For instance, decisions in government housing provision are basically made by the local government, while in a joint scheme of housing provision the actors involved in the cooperation all play a role. Households are hardly involved in the first two phases of housing development. The housing providers may only have some general ideas of local people's housing demand, based on previous experiences, references from urban housing development, and local traditions and culture. But they do not consult future residents about their preferred energy choices and the ways in which they prefer to be supported with low carbon alternatives for their energy consumption practices.

Despite these different models of housing provision and the geographical differences, the application of low carbon alternatives in fact shows major similarities. Selected house-related technologies and materials are almost the same in all case studies. To a large extent this can be attributed to the uniform standards and norms that apply to new-built housing in China. It also reflects a wide acceptance of solar water heaters in rural China and a common demand for central space heating. Grid-related technologies are applied differently, due to differences in available local resources and infrastructure. For example, only small-scale central heating systems were used in Inner Mongolia due to the absence of large-scale heat supply companies and a heating network. But in two of the buildings in that case study, environment friendly ground source heating technology was adopted by a private property developer, which indicates a significant step in promoting low carbon rural housing provision.

Connections to the local energy grid or network usually depend on decisions made by the local authorities. As grid-related low carbon alternatives may serve many sectors, it makes sense for local authorities to be engaged in the decision making on these grids. House-related options usually are decided by those who are involved in the construction phase. In most cases, this will be the property developer.

Table 5.5 Overview of empirical findings from the case studies

Case	Arrangements	Key actors stage 1	Key actors stage 2	Key actors stage 3	Applied house related low carbon alternatives	Applied grid related low carbon alternatives
Case 1	state led project	Village committee	Village committee	Village committee, households	L2, L4, L8, L9, L10	L13, L15
Case 2	Joint venture schemes	Village committee, property developer	Property developer	Property developer, households	L2, L4, L8, L9, L10	L13, L15
Case 3	Private provision	Property developer	Property developer	Property developer, households	L2, L4, L8, L9, L10	L14, L15

5.5. Discussion and conclusion

With a strong focus on rural development in China, rural areas go through a transition which affects both the rural economy and rural society (Long et al., 2007). Since the long-term strategy 'building a new socialist countryside' was proposed in 2005, the construction of rural infrastructures and new housing projects are emphasized by local governments. Traditional stand-alone houses are regarded as problematic because of the waste of land, materials, funds and energy, and the violation of building standards. With rural economic development, land scarcity has become a prominent issue, resulting in an upsurge of transforming decentralized rural housing towards concentrated rural housing in the past decade, especially in regions close to urban.

All three different models of concentrated rural housing provisioning showed that concentrated rural housing leads to an improvement of the energy efficiency of houses when compared to traditional stand-alone houses, for two main reasons. Firstly, concentrated houses can be more easily connected with (central) energy networks and improved energy grids or infrastructures, thereby increasing the energy efficiency of individual houses. Secondly, enhanced thermal insulation of new build houses (under the relevant building norms and regulations and/or via promotion by housing providers) contributed to improved energy and carbon efficiency. It is worth noting that improved energy performance may not necessarily lead to net climate mitigation, since the energy consumption levels of rural households tend to rise together with the improvement of their overall quality of life and the resulting higher levels of comfort and consumption. But compared with traditional rural housing, the new housing projects result in an improved ‘carbon efficiency’ of the living environment in rural China.

In our research, the emphasis has been on decision making processes and not primarily on the low carbon technologies themselves. It can be concluded that in all three modes of housing provision providers are the key decision-makers, from local governments to private property developers to providers of energy infrastructures. Rural households, as end-users of new developed houses, turn out to be scarcely involved in decision making processes for low carbon rural housing. The interests of householders are to some extent represented via village committees and the official regulations concerning consent of the villagers on specific occasions. Direct communication with householders on (the use of) low carbon alternatives for domestic consumption practices however are scarce or non-existent. Since household participation can be regarded as of key importance in accelerating the low carbon transition in rural housing (Hall and Hickman, 2011), it is essential to inform and include citizens/householders more frequently and intense on/in decision making on low carbon alternatives in the future.

We documented for all case studies that low carbon alternatives are being applied within the new housing provision. Low carbon technologies, such as insulation materials, central heating systems and the use of renewable energy sources, have diffused to some extent within the rural housing market. In all three development and decision-making models more or less the same set of low-carbon alternatives are being applied. Although affected by market dynamics to an increasing extent, the Chinese building sector is still heavily under state influence. Taking into account the top-down institutional system in China, the dominant role of local governments in the urbanization process (Xu et al., 2011) would be expedient to promote the application of grid related low carbon alternatives. The impact of regulations concerning building construction and energy conservation play an important role in decision making processes, and a further strengthening of regulatory frameworks seem to be an important future instrument for low carbon transition. In joint venture and private projects economic incentives and administrative measures proved important to get low carbon developments from the ground and to accelerate the deployment of these technologies. Ground source heat pump technology as introduced in the case of private sector provision provided a good example of niche-innovations being driven by economic subsidies and the promise of spurring sales to a considerable extent. For the future, market oriented incentives will be instrumental to increase the possibilities for extra investment by the private sector to accelerate the adoption of low carbon building technologies. In all three cases, similar transformations in space heating systems were documented. Because of the large demand for central space heating systems in northern rural China, technological innovation and diffusion in this area turn out to be of essential and strategic importance.

Providers of rural housing projects should not just follow established routines and imitate urban building constructions, but instead be aware of the specific barriers and opportunities that a rural setting brings. Next to the further development and application of low carbon technologies, capacity building and awareness rising among local providers and the development of pro-active communication and participation strategies for residents are crucial.

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Chapter 6. Conclusion

6.1. Introduction

The issue of climate change has brought along great pressure for contemporary China, implying a major challenge for the existing model of economic development both in urban and rural areas. It also brings along potential opportunities for a societal transformation towards sustainable development. ‘Low carbon development’ is being promoted in many parts of the world as a way to stimulate economic growth and social development through an intensified use of low carbon energy sources. This idea has also spread to various fields and sectors in China. China’s actions to tackle climate change currently focus primarily on the control of (energy) emission intensities, and have set foot mainly in industrial production, transportation and other fields of urban development. Residential energy consumption also significantly contributes to national carbon emissions, ranking only second to the industrial sector, and is drawing more and more academic attention. Recent rapid economic growth in China boosted fast growth of income and consumption expenditures of both urban and rural households, thereby causing substantial increases in household energy consumption. Urban household behaviour has been taken into account to a certain degree in the context of, for example, ‘building a low carbon city’ and ‘promoting low carbon lifestyles’. Rural household energy consumption in China with its specific particularities, however, receives much less attention in both practical policy making and in academic studies.

Domestic energy consumption in rural China is a complex phenomenon that should not be approached from an isolated, technology centered perspective. Energy consumption is connected to economic development and to rural ways of life in a particular way. Historically, many rural areas in China suffered from (commercial) energy shortage. This situation of energy scarcity lasted until the 1990s, when rural energy security was put on the policy agenda. From that moment onwards, the countryside went through a fast process of energy commercialization. Triggered by the growth of rural incomes and the improvements of rural markets for commercial energy sources, rural areas in many parts of the country nowadays show a steady increase in commercial energy consumption. As a result, the rural area has become an important battlefield for tackling climate change as well, with an imminent need to mitigate CO_2 emissions caused by rising commercial energy consumption. Next to CO_2

emissions, energy-related forms of economic poverty, heavy dependencies on traditional biomass and the deterioration of the ecological environment all contribute to the need of obtaining better insights into the changing patterns of domestic rural energy consumption. Such insights may provide an important contribution to a long-term vision and policy perspective that aims to reduce climate impact while at the very same time improving the quality of rural lives and lifestyles by providing householders with access to low carbon options.

To investigate the drivers and barriers towards a more sustainable development of rural areas in China, this research uses the theory of ecological modernization for analyzing the potential contribution rural householders can make to the low-carbon transition. Rural households are considered as key actors in the energy transition, since reduction of CO_2 emissions is closely linked to changing domestic routines of energy consumption. Low carbon futures imply low carbon forms of housing, climate-neutral forms of warming and cooling the homes, climate-friendly cooking and low-impact forms of travel. These kinds of lifestyle changes depend first of all on the willingness of householders to contribute to a low carbon transition. How do Chinese householders perceive and evaluate the risks of global warming and how willing are they to make changes in their everyday life and their existing patterns of energy consumption? One of the assumptions of our study is that the willingness and the potential for householders to contribute to the low carbon rural energy transition depends not just on their incomes and (environmental) values and awareness, but also and crucially so on the behavioural alternatives that are being made available to them via the systems of provision for rural housing and energy consumption. So, individual opinions, values and behaviour have to be analyzed in close relationship with the systems of provision which serve householders with the infrastructure, the products and the services that they use in everyday life.

Against this background, our study aims to explore the possibilities for a low carbon transition within patterns of domestic energy use in rural China, using the following research questions to target four crucial elements of this transition:

- What is the contribution of rural residential energy consumption to greenhouse gas emissions in China?
- What basic attitudes and perceptions do rural residents display towards renewable energy use, and what implications do these have for policies promoting renewable energy development in rural China?

- What is the contribution of different energy use practices of rural households to greenhouse gas emissions in China, and which factors play a role in the (non) development of low carbon domestic energy use practices?
- When considering the provision of housing, in what ways are decisions being made regarding low carbon (behavioural and technological) alternatives for future rural domestic energy consumption practices?

This chapter summarizes the main empirical findings and conclusions for all four research questions. It also puts the findings in a broader perspective of a low carbon development model for rural China. The next section (6.2) gives an overview of the climate impacts of rural residential energy consumption and its contributions to national carbon emissions. Section 6.3 presents and discusses our findings on perceptions of rural residents towards a low carbon future. Section 6.4 provides a detailed discussion of rural household energy use practices by opening this ‘black box’ to examine the transformation of household energy use behavioural practices and its direct driving factors. Systems of rural energy provision and their modernizations are discussed in Section 6.5. The chapter concludes with an outlook of future energy dynamics in China and a discussion of implications for future research.

6.2. Climate impacts of rural residential energy consumption

Until now, domestic energy use in rural China is strongly dominated by conventional biomass combustion. The use of straw and firewood accounted for more than 70% of the residential energy consumption mix in 2007, with commercial energy uses - including coal, electricity, oil and others - accounting for only 20% (this research) or 25.1% (in 2008) according to Yao et al (2012). Because of the use of low efficient combustion systems (devices) for conventional biomass in rural households, high levels of indoor and outdoor air pollution as well as high levels of CO_2 emissions are shown to result. In the last decades however, commercial energy consumption was on the rise and sharp increases in their overall share of domestic energy consumption are expected to occur in the future. This again results in foreseeable high pressures for mitigating the climate impacts in rural China.

Against this background, we estimated the CO_2 emissions caused by rural residential energy consumption in Chapter 2, providing evidence of the emerging climate pressures. The estimated CO_2 emissions from rural commercial energy consumption in 2009 were 268.8

million tons, more than twice the size of emissions in 2000. This result is in line with other research, for example Yao et al (2012), in which an annual CO_2 emission growth rate of 9.3% was found between 2001 and 2008. Total rural CO_2 emissions (from commercial energy consumption) contributed around 4% to national total emissions from fuel combustion (according to IEA (2011)[39], and 2.8% according to Zhao et al (2012)). Per capita CO_2 emissions from residential energy use in rural China were estimated to equal 377.1 kg in this research, much higher than the estimates provided by Liu et al (2011) using an input-output method (direct rural per capita emissions were around 110 kg CO_2), but lower when compared to 5.1 tons CO_2 as the national per capita emission (IEA, 2011). However, since commercial energy consumption in rural areas only accounts for around 1/5 - 1/4 of total residential energy consumption, the actual total CO_2 emissions from rural domestic energy use may contribute up to 20% to the national emissions by a rough estimation.

The gap between rural and urban commercial residential energy use is also reflected by a comparison of carbon emissions. Urban per capita CO_2 emissions, according to our estimation, were 63% higher than rural per capita (commercial energy) emissions in 2009. But this is not the case when taking conventional biomass combustion into account. With emissions from traditional biomass use being included, rural CO_2 emissions per capita caused by residential energy consumption were 73% higher than urban residential emissions per capita in 2007. As mentioned above, traditional biomass is still very dominant in rural energy use and may be sustained over a long term. As predicted by Tian et al (2011) via scenario analysis, traditional straw and firewood use will account for 47.1% - 59.4% of domestic energy consumption in rural China until 2020. Carbon emissions from traditional biomass use are excluded from official carbon accounting data. The carbon emissions caused by rural domestic energy use are usually underestimated because of this.

National (urban or rural) averages do not provide information about spatial differences or divergences between different constellations of people. For instance, the case study of a well-off rural area (Chapter 4) showed that per capita emissions of (sample) rural residents were 1426.9 kg CO_2, and hence were much higher than the national average that we have estimated. The results for the spatial distribution of CO_2 emissions show an evident variance between regions, similar to findings in other studies (Feng et al, 2009; Zhao et al, 2012). For example eastern coastal (relatively rich) areas show larger shares of commercial energy consumption and higher carbon emissions than other areas (Chapter 2). We further find that households

[39] According to IEA statistics, China's CO_2 emissions from fuel combustion in 2009 were 6877.2 million tons.

within higher income groups (or from richer regions) have larger carbon emissions because of their higher energy consumption (Chapter 4). Expected household income growth due to rapid urbanization and rural development is therefore an important trigger of increased greenhouse gas emissions in China.

Along with the progress of economic development, an energy transition is taking place to some extent in rural China (Jiang and O'Neill, 2004). Historical change of the energy mix indicates a shift from dominant traditional biomass use to a more and more combined traditional and commercial energy use. The transitional dynamics are still going on, with a shift to a larger involvement of renewable energy use. Different countries may show different pathways in terms of 'energy (source) transition'. As reviewed in Chapter 4, a country may follow the 'energy ladder' (Leach, 1992; Kirk et al, 1994) or 'fuel stacking' model (Masera et al, 2000; Heltberg, 2004) as discussed by different schools of scholars. The former stresses the upgrading of energy sources with a switching from traditional biomass use to more convenient energy sources (commercial energy) and more efficient energy systems. The later model emphasizes a diversification of energy sources and suggests that, instead of switching between fuels, households choose to use a combination of modern fuels and traditional fuels. Both models can be found in different parts of rural China. The case study in Shandong (Chapter 4), as a well-off rural area, showed some features of an 'energy ladder' transition. Less and less traditional biomass is used by local rural households in the case villages; with 37.6% of households using traditional biomass stoves, this figure is much lower than other areas. Convenient access to electricity, coal and other commercial energy to a large extent facilitates the decline of traditional biomass use. The new style of (concentrated) housing provision (Chapter 5) also makes it possible to abandon traditional biomass use. However, in some northeast and southwest regions, the situation is totally different. A large proportion of straw or firewood is used as dominant domestic energy sources in these areas (Chapter 2), and abundance in biomass resources and economic poverty consolidate this heavy reliance. The reliance on traditional biomass in these regions usually coexists with the introduction of new or more commercial energy sources, and hence indicates that the 'fuel stacking' model is probably more appropriate.

In sum, commercial energy consumption of rural households is still at a low level, but per capita rural energy use shows an increasing tendency. The often neglected traditional biomass use has an enormous potential for climate change mitigation. Conventional utilization and low efficient combustion systems are main characteristics of its use and major driving forces for massive carbon emissions. Technological innovation and creative policy making with regard to commercialization of biomass energy are urgently demanded for a low carbon transition. Diverse climate conditions, resource endowments and economic development have driven regional differences. Different focal points and strategies need to be identified in different regions for mitigating the relevant carbon emissions or promoting a low carbon transition, resulting in context-specific policy making. The evaluation of climate impacts of rural domestic energy consumption has indicated diverse directions to mitigate these impacts, which require transformations of energy source, energy utilization patterns, energy technologies and distinct policy making. Any of these transformations should in the end interact with the behavioural change of energy end-users, as the two sides are influenced by each other. An in-depth inspection of the perceptions and behaviour of rural households and their energy use preferences is needed for understanding the formation and change of these behavioural practices.

6.3. Local perceptions on a low carbon future

China has set ambitious targets on developing renewable energy. Use of renewables in rural areas is also on the rise, which to some extent is leading a low carbon transition of domestic energy use. Public acceptance of those sustainable energy technologies is crucial for their successful introduction to the society (Huijts et al, 2012). Willingness of householders to contribute to this process is of significant importance, since their understanding of low carbon futures determine the extent to which they are willing to adapt their energy use behaviour. Influencing rural household willingness to change their energy behaviour may therefore be an important focal point in environmental policy making. So far, as we have seen in Chapter 4, environmental or climate benefits and concerns do not seem to play a role in guiding the daily energy use behaviour of rural households. However, environmental awareness and concerns, especially related to industrial pollutions taking place in their nearby living environment, are widely observed.

In general, rural householders have vague understandings of ‘low carbon development’ and ‘low carbon energy’. For example renewable energy is known as an innovative environmental friendly energy source, but its contribution to mitigating global warming and climate change is hardly recognized (Chapter 3; Duan, 2010). Our examination of rural social acceptance of renewable energy deployment in Chapter 3 showed that rural residents are generally supportive of renewable energy deployment. This finding is consistent with other research. For example Yuan et al (2011) found a high level of social acceptance and public awareness of solar water heaters in Shandong. We further found that the positive behavioural intention to pay for 'higher cost' of renewable energy production increases with household income, individual knowledge (as found by other studies, for example Ek, 2005; Zografakis et al, 2010) and beliefs about renewable energy use, and decreases with age.

Given the current perceptions of local householders on low carbon renewable energy use, a generally supportive attitude can be observed. Such a positive attitude to some extent implies an emergence of people's new values and ideology, which for example lead to increased environmental awareness and higher support for ecological protection. Along with societal progress and economic development (triggering higher education and income levels), it can be expected that environmental interests and ecological protection values will be enhanced and will further guide changes in behavioural practices towards low carbon energy consumption. However, at present a large gap exists between an emerging positive perception on low carbon transition and actual behavioural change. Appropriate environmental policies are needed (Duan, 2010), with an emphasis on enhancing information and communication and popularizing environmental knowledge about low carbon efforts at the local level, to reduce this gap.

6.4. Transitional household energy use practices

Energy use practices of rural households show a large variety in China. Energy is used by diverse daily practices including cooking, water heating, space heating, lighting, appliance use, entertainment and transportation. Consumed energy sources are also various, covering conventional sources such as traditional biomass, coal, oil, LPG and thermal electricity, centralized renewable energy sources (for example, wind power and hydropower), and decentralized renewable energy sources (for example, solar water heater, solar PV and biogas). It is common that a multiple fuel (and diverse devices) strategy is adopted for one energy use practice by rural households. Amongst all kinds of energy use practices, space heating is found to be the largest carbon emission source in rural China, accounting for around 60% of total residential emissions (Chapter 4). Cooking, transportation and others have different contributions. The mix of these contributions varies among different groups of households, and also keeps changing along with the transition of energy use practices.

A transition of energy use practices of rural households is first found to be brought along by the modernization of household lifestyles, which is taking place in rural China. The modernized life styles imply improvement of rural development; however, they also entail a potential increase of carbon emissions. Economic factors are one of the major drivers of the energy transition and change of household lifestyles, as recognized in this research and other studies (Feng et al, 2009; Warr et al, 2010). A comparison of different income groups (Chapter 4) showed substantial differences in household daily practices which also would lead to different carbon footprints. Along with increasing income levels, the (energy) investments in practices like transportation and water heating are expected to rise, while the relative energy shares of practices for basic living, such as cooking and space heating, decrease accordingly. In this energy consumption mix, the proportion of coal consumption drops but gasoline use is on a rise. Abandoning installed biogas production found in one case study (Chapter 4) also reflects that people are inclined to change (abandon) a traditional, time and labour consuming lifestyle. The lifestyle transition may be closely related to housing provision as well. Housing styles have lock-in effects on the energy use behaviour of occupants. Land scarcity and rapid urban expansion have triggered the demand for new styles of housing provision (Chapter 5).These new types of rural housing to some extent transform domestic energy use practices into more modern ways. In general, in rural China we observe a transition towards modern rural lifestyles, together with modernized household energy use practices, which betokens a high-carbon transition in terms of gross emissions.

Within each energy use practice, however, a low carbon transition is taking place to some extent. A rough comparison of the emission effects of using different energy sources for different domestic energy use practices (Chapter 4) has shown a shift towards low carbon energy use. For example, as for the practices of cooking, space and water heating, using energy sources such as electricity, LPG and natural gas results in lower levels of carbon emissions than using energy sources like firewood, straw (combusted in a traditional way) and coal. Such a shift is happening in different parts of rural China, with a decline of traditional biomass use. Renewable energy sources like biogas and solar energy (used for cooking and water heating) have shown a dramatic development in recent years (Chapter 2), and can be regarded as low-carbon sources most of the times. The use of electricity driven means of transport results in lower carbon emissions than using gasoline for transportation. The case study in Chapter 4 found that 70% of the sample households possessed and used electric bicycles for daily transportation.

A low carbon transition basically demands a behavioural change, with the introduction of new energy saving behaviour and/or the abandoning of certain high climate change impact behaviour. To promote a behavioural change among rural households, a profound understanding is needed of the formation and transformation of their energy use practices. Resource endowments and social and economic dynamics set the basic and broad background where energy resources are provided or limited for rural households, as we have discussed above. A lifestyle explains the shaping of routinized behavioural practices on the one hand, while the specific contexts of energy provision directly influence or determine the available energy options and practices on the other hand.

On the one side, individuals make energy choices taking into account their affordability, comfort and convenience, and also with a judgement based on their values, views, habits and culture. Modernized lifestyles, such as increased reliance on driving cars for daily transportation, are emerging in rural China and are driving the transition of energy use practices to a large extent. However, the transition does not always take place. Conventional lifestyles may also restrict or slow down the transition towards a modern lifestyle. Culture, habits and traditions may influence people or constrain them to adhere to entrenched lifestyles; preference of local households to eat steamed bun cooked on a traditional biomass stove, as found in Shandong (Chapter 4), is an example.

On the other side, transition of energy use behavioural practices is closely affected or driven by the specific context of energy provision. An improved rural market of commercial energy in recent years makes it possible for rural households to switch to modern lifestyles and modernized energy use behaviour in some areas. They allow people to shift from a dependence on traditional biomass use to the use of commercial energy sources such as coal, electricity, oil and gas. Part of those commercial energy sources are renewable, such as wind, hydro and solar electricity. Decentralized renewable biomass energy use in rural China is also emerging as a promising means to solve the low efficiency and pollution problems of traditional biomass use. The ongoing expansion of renewable energy provision is pushing a low carbon transition of domestic energy use.

Focusing on low carbon transition of domestic energy use in rural China, basic ideas of ecological modernization are introduced into this research. Two branches of ecological modernization are emphasized: modernization of lifestyles and life quality of rural households, and modernization of (carbon) performance of domestic energy production and consumption.

Transitions in terms of both modernizing lifestyles and modernizing energy consumption practices have been discussed above. However, these transitions also have to be analyzed in close relationship with the systems of provision which serve households and the infrastructures, networks, products and services that they use in everyday life.

6.5. Modernizing systems of provision

Along with the progress of commercialization of rural energy and the fast development of renewable energy in recent years, rural domestic energy provision has diversified, as summarized in Figure 6.1. Besides dominant traditional biomass use, so far access to commercial energy sources such as coal, oil, LPG and electricity has been easily and widely acquired by most rural households. A large share of electricity is generated from thermal power, with power output of thermal power generation in 2010 accounting for 80% of total electricity output[40]. In recent years new (i.e. nuclear) and renewable electricity generation boomed resulting in a steady rise of their share in total electricity production; in 2010, the share of installed capacity of new and renewable electricity generation had increased to around 26.6%[40]. Large-scale hydro, wind and solar power generation is connected and delivered to central grids (together with thermal power) and transmitted to rural households. Electricity providers are mainly state-owned enterprises. Some decentralized biomass or waste power generation plants have also been built in rural China, and provide electricity for households within a certain region. Other forms of decentralized renewable energy generation are also becoming increasingly popular in rural areas. Examples include small-scale biogas provision, household biogas production, small-scale hydro power and solar energy production. These forms provide energy directly to households, while in some systems rural households may also behave as co-providers and get involved into generating (for example, biogas, hot water, electricity) energy for themselves or others.

[40] Data source: China Electric Power Yearbook 2011.

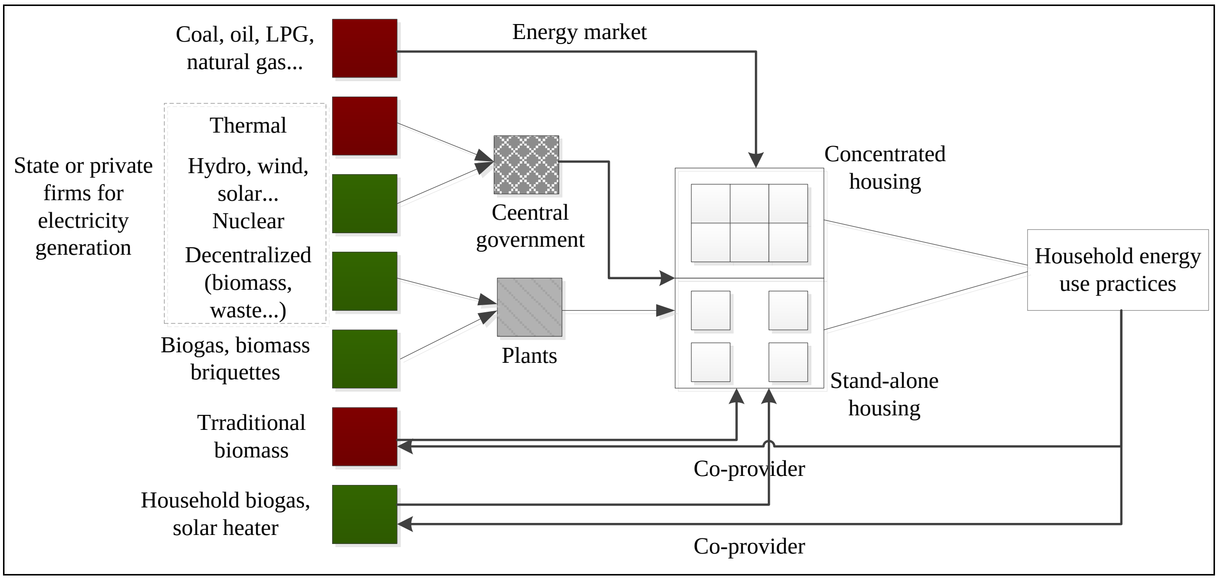

Figure 6.1 Diversified systems of energy provision in rural China
(Note: the red block indicates fossil fuel use; the green block indicates renewable energy use)

Historically, transition of energy provision systems went through different pathways in different regions or countries. For example, in the UK the shift went from biomass to coal, to the rise of networked systems (Rutter and Keirstead, 2012); in recent years, transitions are also witnessed towards decarbonized energy systems with improvements in the energy efficiency of existing systems and cleaner energy substitutions (Shackly and Green, 2007). Systems of provision relevant for rural energy use in China are also going through a process of transition, and show characteristics of (ecological) modernization. First, as mentioned above, improved commercial energy supply via energy markets in rural China has increased the access of rural households to commercial energy and reduced their reliance on traditional biomass sources. Second, the rapid increase in renewable energy provision in rural areas greatly contributes to de-carbonization of the energy provision systems. Third, decentralized modern energy provision systems are emerging as viable alternatives in some areas. These decentralized systems can overcome the vulnerability to disturbances in the supply chain of centralized energy supply systems. Moreover they often fully utilize renewable energy sources (Bouffard and Kirschen, 2008), and enable the participation of decentralized (private) actors in the provision, beyond state-owned firms. Fourth, rural housing provision is modernized along with the promotion of the 'new socialist countryside' construction, and has greatly altered the energy provision to rural households and their energy use practices.

Between diverse energy supply and household energy use practices, as shown in Figure 6.1, the housing provision is playing an important role. Traditional stand-alone houses are still the most common housing style in rural China. However, they are increasingly being replaced by multi-story apartment buildings due to government policies aimed at dealing with growing land scarcity and modernizing the countryside. The case study in Chapter 4 confirmed that the largest energy consumption and CO_2 emissions come from space heating in stand-alone rural houses. Concentrated housing in multi-story apartment buildings was found to have higher energy efficiency and better living conditions for rural households (Chapter 5) and in this way contributes to a low carbon transition of rural housing. But the better energy performance of concentrated rural housing may not necessarily imply lower carbon emissions as compared to stand-alone housing, since the modernization of housing styles is accompanied with a modernization of household life styles that consume more energy.

The different available systems of energy provision in rural China show various characteristics of modernization. For example, the efficiency of energy production has improved in thermal electricity generation, more cleaner and renewable energy provision (technologies) are available for rural households, while low carbon materials and technologies are increasingly adopted in the construction of rural houses. A low carbon transition of rural energy use practices also demands an ecological modernization of systems of energy provision. As discussed above, so far majorly technological innovation and modernization contribute to this process; in addition, an effective diffusion of modernized technologies and the involvement of key actors and citizen consumers are crucial elements as well.

To promote a more rapid transition towards low-carbon energy use in rural China, both energy-related markets and the diffusion of technology need to be improved. As found in the case study of Chapter 4, low quality coal from unstable suppliers is widely being used. Lack of rules on market access and incomplete regulations have restricted the standardization of market operations. Large gains in carbon emission reductions can be obtained from more strict coal supply regulations and their enforcement. Projects of decentralized renewable energy provision are carried out in some rural areas, including for example small-scale or household biogas production and biomass briquettes production. These renewable energy sources may to some extent substitute the use of commercial energy or traditional biomass, and hence lower the climate impacts of household energy use, provided they are effectively utilized. Failure of a household biogas project was found in Chapter 4, consistent with the findings in Han et al (2008). The failure in our case study was attributed to inappropriate volume design, lack of raw materials, insufficient technological maintenance and insufficient supervision on subsequent operation. Technology innovation is usually not a problem in the implementation of these projects. But successful implementation of new technologies poses major challenges to project management, institutional arrangements and consumers' participation. More attention needs to be paid to those challenges in order to successfully promote low carbon energy use.

Modernizing systems of energy provision crucially depends on choices made by the decision makers in question. For instance in rural housing provisioning (Chapter 5), local authorities and private property developers are the main housing providers and thereby also the major decision makers about the use (or not) of low carbon technologies. Both administrative regulations and market-oriented incentives can be suitable instruments to induce these agents to adopt low carbon applications in rural housing provision. The transition of housing and related energy provision systems determines to a large extent the transition of rural households towards low carbon energy use practices.

Rural households in China can to a large extent be conceptualized as passive or 'captive' consumers of energy. For example, most households are not aware of the kind of electricity they are using. Thus the 'cleanliness' of the electricity they use mainly depends on the national and regional electricity infrastructure and on the energy sources used for generating electricity by the operators using this infrastructure. Likewise, households in our case studies are not involved in the decision making about new concentrated housing provision. Instead, they are passively adopting end-users, as also found also in Monahan and Powell (2011). It is important to realise, however, that technological improvements tend to be more effective when the end-users of the technology are involved in their decision making. In addition, provision of information about low-carbon energy sources, carrying out public opinion surveys and designing distinct consumer strategies may be suitable ways to promote the use of low carbon energy sources among end users.

6.6. Energy dynamics and implications for future research

This research has analyzed domestic energy use in rural China from a perspective of ecological modernization of energy production and consumption. Its main contribution to the existing literature lies in the focus on behavioural practices of rural household energy consumption. A social practice model conceptualized the research on this aspect. Application of this research approach within environmental sociology also contributes to the existing literature on ecological modernization of consumption, particularly in its application to transitional economies. In addition, the in-depth examination of Chinese rural energy issues in this study provides a practical contribution to the existing knowledge about rural energy utilization, climate impacts and pathways towards a low carbon transition in rural China. In particular, the empirical results may provide an important input into policy discussions about China's rural energy strategy and climate change mitigation measurements. In doing so, however, it is important to take the limitations of the research into account. Case studies are used to answer most research questions, with samples sizes of households, individuals and communities being relatively small. Considering the larger contribution to CO_2 emissions of the northern regions of China, this research conducted case studies only in the northern provinces. Both the sample scale and the geographical scope of research will need to be extended in the near future to check the robustness of the research findings for other parts of rural China and for other developing countries undergoing similar processes of economic transition.

Energy security and climate issues pose great challenges to China, the world's second-largest economy. Ongoing adjustment in energy strategy is of significant importance in this transitional economy, to cope with the increasing import dependency of oil and reduce the large dependence on coal. Some energy dynamics are expected to occur in the near future, and to raise the range of uncertainty in studies of energy use practices and their transformation. First, new and renewable energy sources will expand rapidly. As stated in 'China's energy policy 2012', by 2015 non-fossil fuel consumption should account for 11.4% of the primary energy consumption mix, and the installed capacity of non-fossil fuel power generation should come up to 30%. Nuclear energy development will be steadily propelled in coastland regions. Second, market-oriented reforms will be undertaken in the energy sector, including pricing reforms of coal, electricity, petroleum and natural gas, and the mobilization of private capital for energy provision. Third, patterns of energy supply will be transformed by developing decentralized or distributed energy provision and smart grids. Fourth, continued globalization is expected to accelerate global environmental flows, bringing along big challenges for domestic production and consumption styles. Energy products are increasingly forced to meet international standards, while eco-labeling or carbon labeling of energy consuming products may significantly alter the behaviour of both producers and consumers.

Consumer participation in energy-related decision making may take a big step along with the enhancement of civil society power. For instance, environmental NGOs and environmental movements are getting more and more involved into global and also Chinese environmental and climate decision making.

In sum, transitional energy dynamics are altering systems of energy provision, which provides energy users different options and new ways to get involved into energy use practices. Such changes also imply several interesting aspects that require further research: i). The increasingly diversified systems of energy provision bring along new challenges and opportunities for energy use in a rapidly growing transitional economy. How do these systems balance decarbonizing energy production and economic growth? More insights are also needed to look into the behavioural responses of energy users to the new socio-technical context; ii). Market-oriented reforms of the energy sector will involve the participation of a wider variety of actors. Research probing into how these groups of actors interact with each other and how market-based instruments influence energy consumption choices of rural households may provide an important contribution to the successful implementation of these reforms. iii). China is playing a more and more important role in the world economy. Conversely, global dynamics - like changes in the global energy market or interactions between global powers in tackling climate change - influence the national strategy to a large extent. The policy relevance of future research on domestic energy production and consumption in China may be enhanced by taking this global context into account.

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Appendices

Appendix I Questionnaire about renewable energy use (*chapter 3*)

Questionnaire (No):

Knowledge and attitude of rural dwellers toward renewable energy use

A．Personal information :

1. Gender：

☐ male； ☐female

2. Age：

☐under 18； ☐18-30； ☐31-40； ☐41-50； ☐51-60； ☐over 61

3. Occupation：

☐family farming； ☐work for other agricultural production； ☐TVE workers； ☐work for village committee； ☐small business； ☐professional； ☐student； ☐none

4. Education：

☐illiterate； ☐primary school； ☐junior school； ☐high school； ☐college； ☐graduate and above

5. Individual income per year(2010/ RMB Yuan)：

☐under 3000； ☐5000-10000； ☐10000-20000； ☐20000-30000； ☐30000-40000； ☐40000 above

6. Household income per year(2010/ RMB Yuan)：

☐under 10000； ☐10000-20000； ☐20000-30000； ☐30000-40000； ☐40000-60000 ☐60000 above；

B. Knowledge and concern on energy and environmental issues:

7. Regarding rural energy issues, which of the following statements comes closest to your opinion?

☐ We are suffering rural energy shortage；

☐ Rural energy is quite sufficient, also with high quality；

☐ Commercial energy is lacking, but traditional biomass is sufficient

8. How do you find the renewable energy：

☐ Renewable energy is new and regarded as important and clean energy in national strategy

☐ Renewable energy is expensive, but not better than traditional energy

☐Know little about it；

9. Renewable energy is a kind of energy reproducible and sustainable, which options do you think belong to renewable energy use?

☐solar water heater, solar cooker； ☐wind power； ☐hydro power；

☐biomass generation； ☐biogas； ☐biomass briquettes； ☐ no idea

10. Regarding rural environmental issues, which statements do you agree?

☐Suffering energy shortage

☐Suffering serious air pollution

☐Suffering serious water pollution

☐Impacts of global warming becomes more and more serious

☐No environmental pollution

11. It should be balanced to protect environment or develop economy, which statement comes closest to your view?

☐Environmental protection should be the first priority；

☐Developing economy should be the first priority；

☐Not sure；

C. Cognitions of impacts of renewable energy deployment:

12. Nowadays, many villages are promoting biogas projects, use of solar water heater and solar cookers, do you think the use of solar energy or biogas would have the following effects?

Statements:	**agree 3**	**neutral 2**	**disagree 1**	**No idea 0**
12.1 It would improve public surroundings in rural areas	☐	☐	☐	☐
12.2 It would improve energy supply of rural areas	☐	☐	☐	☐
12.3 It would improve indoor environment, and comfort level of households	☐	☐	☐	☐
12.4 It can protect forest and mitigate greenhouse gas emission	☐	☐	☐	☐
12.5 Increasing renewable energy production could create more employment	☐	☐	☐	☐
12.6 It also may lead to some negative effects, like noise during wind power construction	☐	☐	☐	☐
12.7 High investment demanded by renewable energy utilization would bring higher electricity price	☐	☐	☐	☐
12.8 Instability during renewable energy generation would cause much pressure for the grid	☐	☐	☐	☐

D. Public attitudes and preferences:

13. Nowadays, energy strategies of several countries have ensured the input on renewable energy generation, regarding this, please indicate your attitudes towards the following statements:

Statements:	agree 3	neutral 2	disagree 1	No idea
13.1 All human beings have the right not to be exposed to emissions of hazardous substances due to the generation of electricity	☐	☐	☐	☐
13.2 Decision on rural energy supply should take both low cost and environmental protection into account	☐	☐	☐	☐
13.3 Decisions concerning what kind of electricity sources we should use should not only be made in the political arena, but also be determined by the preferences of individual consumers	☐	☐	☐	☐
13.4 People who are being disturbed by RE power generation (by, for instance, the noise from a wind plant) should be compensated for this unease with some kind of economic remuneration	☐	☐	☐	☐
13.5 All human beings should be responsible for environmental protection, even if they would suffer economic loss	☐	☐	☐	☐
13.6 If green electricity can be produced only at relatively high cost, those who want to consume green electricity should then be prepared to pay extra for it	☐	☐	☐	☐
13.7 Dwellers who are not willing to pay more for green electricity should not be forced to do that	☐	☐	☐	☐

14. Will you support the transition of rural energy toward cleaner and lower-carbon direction?

☐Will

☐Will not

☐Don’t care

15. I prefer electricity which is :

☐ Produced at lowest cost;

☐ Produced in the most environment friendly way

☐ Produced at the same time of creating more employment

16. If the government tends to promote renewable energy use in rural areas, which kind of the following energy use do you prefer to support?

☐ wind power

☐ biomass generation and biomass briquettes

☐ biogas

☐ solar energy

☐ hydro power

17. Would you prefer to see a greater proportion of your power from renewable sources, even if some are slightly more expensive than traditional fuel sources?
☐Would
☐ Would not
☐ Affordable in certain range
18. Will you be willing to pay more for renewable electricity? ☐Yes ☐No
If yes, then, imagine that your yearly electricity bill 1000 Yuan, How much EXTRA would you be willing to pay to get all of your electricity from renewable sources?
☐0-10%（100yuan） ☐10%-20%（200yuan） ☐20%-40%（400yuan） ☐40%-60%（600yuan）
☐more than 60%

E．Measures and policies：

19. You get information with respect to renewable energy from:
☐ TV, newspaper and other Medias
☐ Introductions from neighbors and relatives
☐ Publicity from enterprises
☐ Publicity of governments
20. When deciding upon a rural energy policy, which of the following elements do you think should be the first two priorities?
☐ Reduce energy's impact upon global warming and climate change
☐ Keeping energy costs low
☐ Increase the use of renewable energy
☐ Encourage everybody to save energy
☐ Helping vulnerable people to afford to keep warm
21. There are some barriers to promote renewable energy use such as biogas and solar energy, specifically they are:
☐ Due to the lack of knowledge, residents are not willing to use new energy
☐ Lack of investment, insufficient subsidy
☐ Lack of technological support
☐ Small scale of production, it is time and effort consuming
22. To facilitate renewable energy deployment in rural areas, which policy options do you expect?
☐ To enhance the information communication, making more people learn the benefits
☐ To increase investment support and subsidies
☐ To ensure technical support and maintenance
☐ To ensure providing more jobs for residents
☐ To make potential users benefit from it, using measures such as electricity pricy intervention
23. If your neighbours start to use biogas or solar energy, would you be influenced?
☐ Very likely

☐ Likely

☐ No

24. If you begin to use more environment friendly energy, do you think you will be socially appreciated?

☐Very likely ☐likely ☐no

25. Which role do you prefer to act in renewable energy production and provision?

☐ Self-producer (self-balancing)

☐ Co-provider (also selling extra electricity to others or grid)

☐ Only being a user (buyer)

26. You would participate in renewable energy production:

☐ If the economic condition permits

☐ Only in the case of making profit

☐ If government orders

☐ As long as it can improve the quality of my life

Appendix II Questionnaire about energy use of rural households (*chapter 4*)

Questionnaire (No):

Energy consumption practices of rural households

province		**city**	
town		**village**	
Geographic condition	1) Plain; 2)Hilly; 3)Mountainous		
Start time		**End time**	
Interviewer		**Interview date**	

1. Household Information

Num	**Household members （Relationship to head）**	**Gender** 1=male 2=female	**Age**	**Education** 0=illiterate 1=primary 2=junior middle school 3=high school 4=college and above	**Time at home in 2010(months)**	**Main job in 2010** 0=none 1=household chores agriculture 2=worker for agriculture 3=TVE workers and others 4=small business (please note) 5=professional (please note) 6=students 9=others (please specify)
1	The head					
Other members:						
2						
3						
4						
5						
6						
7						
8						

2. Household income and expenditure

2.1 2010 household income:

Item:	Agriculture & forestry	Animal husbandry	Salary	Earning from farming work	Earning from off-farm work	Small business	Support from relatives	Pension	Others
Annual income (Yuan)									

2.2 2010 household expenditure:

Item	Agriculture & forestry	Animal husbandry	Food	Clothes	Housing related	
Annual expense (Yuan)						
Item	Education	Small business	Health	Transport	Gifts	Others
Annual expense (Yuan)						

3. Energy consumption and renewable energy utilization

3.1 Energy consumption

Item	Power for livelihood	Power for agriculture	Power for animal husbandry	coal	LPG	gasoline	diesel	Oil for production	firewood	straw
Amount/ cost										
price									-	-
3.1.1 In the past 5years, obvious change of firewood or straw use? 1.increased（reason：_____）； 0.no change ； 2.decreased（reason：_____）；										
3.1.2 In the past 5years, obvious change of coal or electricity uses? 1.increased（reason：_____）； 0.no change ； 2.decreased（reason：_____）；										

code:

reason for increase：**a.** improvement of life quality；**b.** easier to get ； **c.** to be chosen as cleaner energy；

reason for decrease：**d.** price rise； **e.** house reforming； **f.** more convenient and cleaner alternative energy;

3.1.3 Which kinds of fuels do you get for free?____

3.1.4 Where do you get this free fuel?____

3.2 The way how energy is used

Items		**Num**	**The way of energy utilization**
Residential use	cooking	1	1 Kang; 2 stove; 3 cooking appliances (_____types)； 4 LPG； 5 biogas; 6 solar cooker; 7 natural gas; 8 others
		2	The main ways: ____________
		3	Main changes in the past 5 years: 1 no change；2cleaner； 3more convenient；4more appliances used；
		4	Who makes the decision for this service? 1 male head; 2 female head; 3 daughter and son; 4 others
		5	Do you like the way you cook? 1 yes; 2 no
		6	You choose current way because: 1 cheap; 2 easy to install; 3 easy to use; 4familiar and traditional; 5 cannot afford other fuels; 6 no other choice
	Space heating	1	1. kang； 2. Stove/radiator; 3. Air conditioner; 4 electric radiator; 5 other_____
		2	The main ways: ____________；
		3	Main changes in the past 5 years: 1 no change；2cleaner； 3more convenient；
		4	Who makes the decision for this service? 1 male head; 2 female head; 3 daughter and son; 4 others
		5	Do you like the way and fuel you use for space heating ? 1 yes; 2 no
		6	You choose current way because: 1 cheap; 2 easy to install; 3 easy to use; 4familiar and traditional; 5 can’t afford other fuels; 6 no other choice
	cooling	1	1.fan; 2 air conditioner; 3.none;
	Water heating	1	1 electric water heater; 2 solar water heater; 3 stove with coal; 4 stove with firewood; 5 biogas; 6 others
	lighting	1	1 ordinary light; 2 energy saving light; 3 biogas light; 4 other_____
	Home appliances (excluding cooking and entertainment appliances)	1	1.clean-appliance; 2.health care appliance; 3. washing machine; 4.others_____________
		2	Purchased in the past 5 years: 1 increased; 0 no change; 2 decreased
	entertainments	1	1. TV; 2.camera; 3. Audio system; 4. radio; 5.PC; 6.musical instrument; 7.others_________
		2	Purchased in the past 5 years: 1 increased; 0 no change; 2 decreased
	transportation	1	1. car; 2.motorbike; 3.electric motorbike; 4.bus, bike

		2	The main ways: _____________
		3	Main changes in the past 5 years: 1 no change；2more comfortable； 3more convenient；
Production use	agriculture	1	Which needs the largest energy input? 1.cultivation; 2.irrigation; 3.transportation; 4.harvest and process; 5.others_________
	Animal husbandry	1	Which needs the largest energy input? 1. Lighting; 2.transportation; 3.feed processing; 4. others________

3.2.1. Are you using solar energy in your house?

1. Yes. 2.No. (to **3.2.2**)

H.1. The SWH installed in your home has been used for _____ years.

H.2 The installation cost of the SWH you are using is _____ Yuan

H.3. The investment on SWH is from________

A. Self-payment; B. governmental subsidy (___%); C. others___________

H.4. The SWH is used for _____

A. Shower; B. washing clothes; C. kitchen hot water; D. drinking; E. others________

H.5. The SWH can be used in _____ days a year.

H.6. Averagely you take _____ baths a week now.

A. <1; B. 1 ~ 2; C. 3 ~ 4; D. 5 ~ 6; E. 7 and above

H.7. After using SWH, the air quality at your home ________; and life quality_________.

A. significantly improved; B. slightly improved; C. did not change

3.2.2. You are not using SWH, because__________

A. more convenient in other way; B. short available time; C. troublesome to install; D. no enough input; E. no available room in current house; F. lack of information and knowledge

3.2.3. Are you using biogas? A. No (to 3.2.6) B. Yes. It has been used for ________years. If you are using community biogas, please skip to 3.2.4.

B1. The investments on biogas was from __________

A. self-payment; B. government investment; C. government subsidy(___%); D. loan; E. others_______

B2. In general, you think the subsidy for biogas construction is ____

A. too little; B. a little insufficient; C. reasonable; D. others_________

B3. After using biogas, the air quality at your home ________; B4. and life quality_________.

A. significantly improved; B. slightly improved; C. did not change

B5. How did the biogas utilization affect the workload of housework? _____

A. increased; B. no change; C. reduced

B6. The capacity of biogas is _______m^3; B7. The output of biogas in 2010_____ m^3

B8. The biogas is mainly used for ______ A. kitchen hot water; B. lighting; C. cooking; D. shower water; E. others____

B9. Please rank the problems which you have encountered during using biogas:__________________

1 insufficient raw materials; 2 know little about technologies for maintenances;

3 not available in winter; 4 difficult to deal with biogas residues; 5 laborsome to use it

B10. Are there professional maintenance services provided?

1 no; 2 yes, who__________________________________; how far_________________

B11.What problems do you find in current biogas maintenances?

1 no maintenance worker nearby; 2 too expensive; 3 bad attitude and quality;

4 not in time; 5 price of fittings is too high; 6 other____________

3.2.4. You pay for the use of community biogas ________per M^3;

3.2.5. The community biogas construction benefits you with respect to:_______

A. no benefit; B. clean energy; C. jobs; D. income from selling raw materials; E. others_______

3.2.6. You are not using biogas, because_______

A. no approval of application of subsidy; B. no knowledge on biogas project (subsidy)

C. subsidy is not enough, insufficient investment; D. the transformation is troublesome

E. prefer other energy_________; F. insufficient raw materials

G. short available time; H. no suitable space for construction; I. lack of knowledge and technology

J. others____________________

3.2.7. What do you think about the purpose of the government to promote rural biogas construction?

1 improve rural energy supply; 2 improve rural environment; 3 protect forest and ecosystem

4 help to reduce household expenditure (chemical fertilizer, fuel); 5 other____________

4． Energy accessibility and provision

4.1. Are you content with current rural energy infrastructure, such as power supply?

A. Yes; B. No，

Because： 1.insufficient supply； 2.bad maintenance； 3.lack of options due to monopoly；

4.2. How and where do you buy commercial energy such as coal purchase?

1. sold in the village； 2.sold in the town； 3.sold in the city

4.3. Is this energy market convenient for you?

A. Yes; B. No,because： 1. Insufficient supplies；2. Inconvenient transportation；

3. others_______

4.4. Is the electricity outage very often in your village?

1 very often, not convenient; 2 sometimes; 3 no, very convenient

4.5. Is it convenient for you to collect biomass?

A. Yes; B. No,because： 1. Lack of biomass; 2. Too far away; 3. others_____

4.6. Is there serious biomass waste in your village? 1 no 2 yes, e.g.__________________

4.7. How do you consider the following factors when making energy choice?

Order________________________

1 whether cheap; 2 whether easy to get; 3 whether easy to use; 4 whether clean; 5whether with stable supply

4.8. The price of electricity for livelihood?_______yuan/kWh; the price of electricity for rural production?_____yuan/kWh

4.9. How do you find current electricity price?

1 reasonable; 2 can be accepted, but should be the same with urban price;

3 too high, I can accept if it's lower than _______yuan/kWh

4.10. If price of electricity or coal is improved, will you reduce household use of them obviously?

1 definitely yes; 2 impossible to reduce the demand; 3 unaffected

4.11. As you know, which subsidy policies are there in your village related to rural energy?

____

4.12. If the energy subsidy is provided, would you use more clean energy to protect environment?

1 yes; 2 no; 3 depends on the subsidy

5． Life quality and lifestyle

5.1. Is there obvious improvement of your life quality in the past 5 years? A. Yes; B. No

5.2. If you have to reduce energy consumption, do you think your life quality would decline with it?

A. Yes; B. No

5.3. If you reduce energy consumption by energy saving actions, do you think your life quality would decline with it?

A. Yes; .B. No

5.4. Do you consider energy saving in your daily practices?

A. quite clearly; B. generally; C. a little; D. not at all

5.5. Which style do you think your household daily life pattern comply with?

A. frugal type； B. moderate type, making ends meet； C. promoting excessive consumption

5.6. Are you aware of health problems caused by the fuel use?

1 yes; 2 no idea; 3 know a little, don't think it matters

5.7. If you are aware of health and environmental problems caused by certain fuel use, would you refuse to use it?

1 yes; 2 no if its effect is not so significant; 3 don't care this kind of effect

5.8. If you can afford other options, would you stop using straw or firewood for cooking and heating?

1 yes; 2 no, because______________________________

5.9. If it's possible for you to decide your household energy use at your option, which way do you prefer?

1 only commercial energy (coal, electricity); 2 diversified, all kinds of fuels;

3 only clean energy; 4 keep traditional energy use and add some other fuels

5.10. Without regard economic restricts, what are main barriers to energy transition of rural households?

1 current energy devices can't be wasted; 2 tradition is not easy to change

3 the supply of modern energy may be not as stable as traditional energy;

4 maintenance of modern energy technologies may not follow up

5 rural dwellers like and accept current energy model, unwilling to change

Appendix III A checklist for interview on rural housing (*chapter 5*)

General questions:

1. How are the houses provided generally in the past years? Is the current case very typical as the average or quite different? Are there relevant or similar cases around?
2. What is the objective of developing/retrofitting the rural buildings? Is it basically for improving rural living environment, vacate more land for agriculture, or saving energy etc.?
3. What is the situation of local economy and the situation of local resources (e.g. industrial structure, GDP, village collective revenue, income per capita…; rich resources, poor resources, basic energy options of households)? How are these elements considered in the planning and decision making of house provision?
4. What are the rules and process of getting access to land? And its cost? Are there any impacts on land use of local rural households?
5. How many houses (buildings) are provided in this project? How many (or what's the proportion) households buy or rent the houses? At what price? Is that affordable for most villagers? Is there also a subsidy mechanism?

During planning and decision making:

6. Who initiates the development of this rural housing?
    - Who is responsible for organizing all those parties that are involved in the planning?
    - And in which way (workshop/focus group/individual interview...)?
7. Who are majorly involved into this decision making process?
    - Is local government engaged as planer, regular or organizer?
    - What are the roles of local Development and Reform Committee (Economic and Trade committee), Building and Construction Bureau, and others like Energy Conservation Office, etc.? How do they cooperate with or affect each other?
    - Are there organizations for instance NGOs that participate or potentially promote the project, and might act on the connections between local government and end-users?
    - Is there any property developer involved in the planning process?
    - Are there qualified advisors involved in the planning with respect to what type of house is built?
    - What kinds of financial parties are involved? How do they benefit?

- Do the end-users participate in the planning or initiation of the house development?

8. Is the house built (partly) due to any pressure from energy related policies, regulations or norms? Or pressure from neighbor villages with advanced experiences?
9. What kind of house is decided to build during the planning?
    - What decisions are made with respect to the site and orientation of houses?
    - How are the grid-connected heating, gas and electricity systems considered? Is there any renewable energy utilization taken into account?
10. Who majorly make the decisions in terms of types of the house and connected grids? Why are such decisions made by each actor?
11. Do you ever expect the participation of end-users in the planning process? If there are end-users involved, in which way do they participate in the decision making?
    - Are they just informed or do they also have chances to show their opinion?
    - Are they widely consulted with or do they choose representatives for participation?
    - Do their comments actually have impacts on the final decision?

<u>During the designing and construction or retrofitting:</u>

12. Are there any standards or norms that have been considered when designing and constructing the house? Are there any differences in this aspect with building construction in urban areas and why different?
    - <Civil building energy conversation regulations>2008; is it compulsory? (including energy conversation related planning, standards, market access, measurement, operation management and reporting..).
    - <The twelfth five-year special planning on building energy efficiency>2012; is it considered especially in terms of its planning on renewable energy use, building energy efficiency standard, rural house energy saving, etc.?
    - <Rural housing construction and technology policy> 2011; is it also considered as guidance?
13. Who are in charge of the designing and construction (retrofitting)?
    - Who takes charge of organizing the designing and construction process?
    - Is the house designed by qualified advisor, developer or government?
    - Is the house constructed by developer or others?
    - Do the villagers participate in the construction? Hired or in other ways?
14. How is the house designed and constructed with respect to low carbon alternatives?
    - How is the house's insulation considered (technologies in terms of roof, wall,

window, selection of materials...) see attached table.

- What decisions are made with respect to the house's internal water, gas, heat, electricity (and other energy) and waste systems?
- Are there any considerations on the house's monitoring and maintenance system?
- How are the grid-connected heating, gas and electricity systems considered? Are there any changes compared to the planning in terms of those low carbon alternatives? If yes, why?

15. Who make major decisions with respect to above alternatives respectively, the advisor, developer, regular? Why do they make such decisions?
16. Does the major decision maker ever consult with opinions from other stakeholders? If yes, how does it work?
17. How do you find those low carbon technologies (insulation, materials, energy systems)? Do they alter traditional construction modes substantially? Are they quite new or familiar to the rural market?
18. Are those technologies easy to be included in the rural housing provision? If more strict and compulsory standards (that may fit urban housing now) are required to be implemented, do you think it is possible or what kinds of barriers might be there?
19. Does the constructer or designer ever consider the impacts of houses on comfort or convenience of occupants and what do they do in this respect?
20. Are rural households also consulted with regarding how the house is built? Are they co-developer or just informed? Do their comments work?

<u>During the house use and maintenance:</u>

21. Who is in charge of the management and maintenance of the house (property manager, or occupants)? How do they work especially in terms of energy management?
22. Are there any rules regarding how those relevant low carbon alternatives should be used?
23. Are energy devices used by households complying with the provision as designed? Are there any systems (energy, gas...) that the households are not willing to use even if installed or connected with the grid?
24. Do any occupants install new appliances by themselves like energy saving lighting, solar water heater, PV panels, etc.? Who intervenes this process ever? Is the decision affected by some organizations? Whom? Who enforces them to do this ever?
25. Does the new housing provision substantially alter the major energy options of rural households compared with traditional standalone houses?
    - What are the changes of energy options and devices used for cooking, water heating and space heating?
    - Does it lower the energy demand of space heating, water heating, and cooking or

not and why?

- Does it decrease or increase the energy expenditure of rural households on these practices and why?

26. Are there metering systems with respect water, heat, electricity use installed? How do they work? Do the metering systems deliver impacts on household (energy) consumption behaviours?
27. Are the occupants satisfied with the new house insulation? Are they content with the grid connected energy systems?
28. Do the occupants also expect changes if they could decide the house construction, what and why, and especially in terms of energy use?

A check list of low carbon elements in housing development

Number	Low carbon alternatives	Key references or policy standards
House related:		
L1	Considering environmental impact when selecting project site	United Nation Environmental Program(2005)
L2	Optimizing building orientation	Glicksman et al (2001)
L3	Application of green roof technology	Nelms et al (2007)
L4	Thermal insulation of walls and roof	Zhang et al (2012)
L5	Application of low-E insulation window technology	Kirby and Williams (1991)
L6	Use of green wall materials	UNEP(2003)
L7	Ample ventilation for pollutant and thermal control	U.S Department of Energy (2009)
L8	Energy efficient lighting system	
L9	Application of (internal) energy efficient space heating system	
L10	Application of (self-contained) solar water heating system (or PV)	Liu et al (2011); Han et al (2010)
L11	Application of green technology monitor and maintenance system	U.S Department of Energy (2009)
Grid related:		
L12	Application of natural gas for heating and cooking	
L13	Application of ground source heat pump technology	Doherty et al (2004)
L14	Central space heating system	
L15	Central water heating system using solar energy	Liu et al (2011)
L16	Combined heat and power system	Zhang et al (2012)
L17	Connected with distributed renewable electricity generation (wind power, bio-fuel, solar energy..)	Liu et al (2011); Han et al (2008)

Summary

As the largest emitter of greenhouse gasses in the world, China is facing great pressure to reduce these emissions in order to mitigate global climate change. Developing a low carbon economy has been initiated in many countries, including China, as a means to tackle this issue. China's actions in tackling climate change have mainly focused so far on setting targets in its national energy strategy, and on implementing measures in the industrial sector and in urban transportation and buildings. The contribution of rural energy use to climate change has largely been neglected. In recent decades, China's rural economy has undergone rapid development, accompanied by a substantial and profound change of rural lifestyles and a gradual transition of residential energy use patterns. This resulted in a trend towards the use of a greater variety of energy sources among rural residents. This rural energy transition is in particular characterized by a steady rise of commercial energy consumption and of energy intensity per capita, resulting in an increase in carbon emissions. As a result, mitigating rural CO_2 emissions and promoting a rural low carbon transition are crucial for China's climate change agenda. Households are considered key actors in the rural energy transition, since reduction of CO_2 emissions is bound up with changing domestic routines of energy consumption. The central objective of this research is to define the existing contribution of rural energy consumption to climate change and to explore the possibilities for low carbon transitions of rural households in China by examining the composition, formation and (potential) transformation of household energy consumption practices.

Western ecological modernization theory is used as the theoretical basis of this study. The social practice model, developed within this theory, offers an integrative model to analyze transitions towards sustainable consumption at the level of everyday life. As such, social practices of household energy use are taken as focal points. Both individual attitudes towards energy use and the structural energy-related provision systems are taken into consideration in analyzing the transformation of household energy use practices.

Official data on rural energy use faces some major shortcomings that hinder a comprehensive evaluation of rural CO_2 emissions. Thus, to understand the contribution of rural domestic energy use to national greenhouse gas emissions in China, a general evaluation on its climate impacts is conducted in chapter two, based on multiple data sources and calculating methods. It is found that the contribution of rural (residential) carbon emissions to

national total emissions might be easily neglected, since only emissions from commercial energy use are taken into account in official statistics, not those from traditional biomass use. This results in an underestimation on rural carbon emissions and mitigation potentials. The estimated CO_2 emissions of rural commercial energy consumption accounts for around 4% of national total emissions, but the commercial energy use is only 1/5-1/4 of rural residential energy consumption. Large emissions and mitigation potentials from traditional biomass use are usually neglected. An energy transition is taking place in rural areas, with the dominant use of conventional biomass gradually being (partly) substituted by commercial energy utilization. Despite this transition, the increase of total rural domestic energy consumption and their carbon emissions may continue for a long time when the rural economy continues its rapid development. Promoting a transformation in the energy structure and of the behaviour of rural energy users is therefore crucial to slow down and reverse this process.

Developing renewable energy is taken as a key strategy to optimize the energy structure and stimulate a low carbon transition. Public acceptance of such sustainable energy technologies is crucial for their successful introduction and penetration. The third chapter applies a socio-psychological framework to analyze rural householders' understandings of a low carbon future by examining their attitudes towards the development of renewable energy in rural China. A case study was conducted in Shandong province. The results show that most rural householders have vague understandings of the 'low carbon' concept, but they are generally supportive to renewable energy development. In particular, a positive behavioural intention to pay for 'higher cost' of renewable energy production is observed among a large part of the respondents. This willingness to pay increases with household income and individual knowledge. It may be expected that continued development of the rural economy and society will result in improvements in rural education and income levels, which will come along with a growing environmental awareness among rural residents and further a change of their behavioural practices towards a low carbon transition.

Energy use practices of rural households show a wide variety in China. These diverse energy use practices contribute differently to greenhouse gas emissions. A case study in north China (Shandong) was carried out to probe into their different contribution, and examine the factors that influence or determine energy use behavioural practices of rural households (chapter four). The results show that space heating in north China is the largest emission source among domestic energy use practices, which accounts for around 60% of household carbon emissions. The variety of rural energy use practices also leads to many possibilities of transition. The most obvious change may be brought along by a modernization of household lifestyles. Economic factors are one of the major drivers of such a transition. High-income groups are found to consume more energy for transportation and water heating, while low-income groups consume more energy for basic living practices such as space heating and cooking. It should be noted that a transition to modern-lifestyles tends to result in higher carbon emissions due to a larger energy consumption demand. However, a low carbon transition is also taking place to some extent within each energy use practice. For instance, natural gas is increasingly used for cooking instead of coal and traditional biomass; and renewable energy such as solar energy and biogas are replacing the use of fossil fuels for water heating and cooking. A low carbon development emphasizes both modernization and de-carbonization of domestic energy use practices, and cannot be separated from changes in the system of energy provision.

Rural housing provision is crucial for future domestic energy use in rural China. The provision of rural housing is increasingly diversifying over the past decade, with variations in type of houses as well as actor arrangements that determine the lay-out of houses, the kind of energy sources used and thus future household energy use. Several case studies of concentrated rural housing provision are conducted in Shandong and Inner Mongolia, China to understand the factors influencing possible low carbon housing (chapter five). The major objective is to look into how decisions are being made regarding low carbon (behavioural and technological) alternatives for future rural domestic energy consumption practices. The empirical results show that providers of houses are the major decision makers with regard to the kind of materials, technologies and energy networks applied in rural housing development. Concentrated rural housing can improve both the energy efficiency of houses and the living conditions of households compared to traditional stand-alone modes of housing, which implies a relatively low carbon housing provision. Local governments, private property developers and local (energy) authorities in principle have the power to select and apply low carbon alternatives. Other energy (related) provision systems are also engaged in a transition of modernizing and de-carbonizing, including improved commercial energy supply, increased renewable electricity generation and decentralized energy provision. However, the transition can to a great extent be attributed to technological improvements within these systems. The transition to a low carbon economy would greatly benefit from strengthening other important aspects, such as improved energy-related markets, decentralized management of energy provision projects, diversified strategies aiming at different agents or actors involved, and

increased participation of rural householders to alter the situation of 'captive consumers' of energy.

In sum, this thesis finds that with rural development and modernizing rural lifestyles in China rural residential energy use is leading to increasing greenhouse gas emissions. Energy use practices of rural households in China have to be both modernized and decarbonized in order to reduce greenhouse gas emissions. A low carbon development demands, on the one hand, improvement of environmental awareness and attitudes, which is starting to play a more important role in the energy use decision making of rural householders; on the other hand, it demands that energy-related provision systems in rural China continue to be diversified, modernized and de-carbonized, and thereby make low carbon alternatives available for rural householders.

Samenvatting

Als 's werelds grootste producent van broeikasgassen, rust er grote druk op de schouders van China om haar emissies terug te dringen met het oog op mondiale klimaatverandering. Om deze problematiek aan te pakken is er in China, net als in vele andere landen, een transitie naar een koolstofarme economie in gang gezet. China's maatregelen om klimaatverandering tegen te gaan zijn tot nu toe voornamelijk gericht geweest op het formuleren van doelen in haar nationale energie strategie, en op het implementeren van maatregelen in de industriële sector, in het stedelijk vervoer en in de bebouwde omgeving. De bijdrage van ruraal energiegebruik is tot op heden grotendeels buiten beschouwing gebleven. In de laatste decennia heeft China´s rurale economie een sterke ontwikkeling doorgemaakt. Dit is gepaard gegaan met aanzienlijke veranderingen in rurale leefstijlen, een gestage transitie in energie gebruikspatronen en een diversificatie van energiebronnen. Deze rurale energietransitie wordt gekenmerkt door een gestage toename van energieconsumptie in de commerciële sector en een stijgende energie-intensiteit per hoofd van de bevolking. Het logische gevolg daarvan is een verhoogde uitstoot van CO_2. Het voorkomen van emissies en het promoten van een koolstofarme economie in ruraal China zijn daarom van groot belang voor het behalen van China's klimaatdoelstellingen. Huishoudens worden gezien als sleutel-actoren in deze rurale energietransitie. Een vermindering van CO_2 emissies hangt namelijk nauw samen met veranderingen in energie-gerelateerde routines in en rond het huishouden. Het hoofddoel van dit onderzoek is dan ook, ten eerste, om de bestaande bijdrage van rurale energieconsumptie aan klimaatverandering te bepalen, en ten tweede, om de mogelijkheden voor (koolstofarme) transities in rurale huishoudens in China te verkennen door de samenstelling, vorming en (mogelijke) transformatie van energie-gebruikspraktijken in en rond het huis te bestuderen.

De in het Westen ontwikkelde theorie van Ecologische Modernisering (EMT) dient als theoretische basis voor deze studie. Het Social Practices Model (sociale praktijken model), zoals toegepast binnen EMT, biedt een geïntegreerd raamwerk voor het analyseren van transities naar duurzame consumptie in het dagelijks leven. Op basis van dit model worden energiegebruiks-praktijken in en om het huishouden als uitgangspunt genomen. Bij het analyseren van de transformatie van deze energie-gebruikspraktijken worden zowel individuele attitudes op het gebied van energiegebruik, als structurele eigenschappen van (energie-gerelateerde) leveringssystemen in beschouwing genomen.

Officiële data over ruraal energiegebruik in China zijn beperkt en belemmeren een enigszins volledige evaluatie van rurale CO_2 emissies. Om de bijdrage van rurale huishoudens aan de totale uitstoot van broeikasgassen in China toch te bepalen, is er in hoofdstuk 2 op basis van diverse bronnen en rekenmethoden een algemene evaluatie gemaakt. Hieruit komt naar voren dat de bijdrage van rurale huishoudens aan de totale uitstoot (op nationaal niveau) makkelijk over het hoofd kan worden gezien, aangezien alleen emissies van de commerciële sector in de berekening worden meegenomen, en dus niet de emissies voortkomend uit het traditioneel gebruik van biomassa. Het resultaat is een onderschatting van rurale emissies en dus ook de mogelijkheden voor mitigatie. De bijdrage van energieconsumptie in de commerciële sector aan de China's totale CO_2 uitstoot wordt geschat op 4%. Commercieel energiegebruik is echter maar 1/5-1/4 deel van de energieconsumptie in rurale huishoudens. Significante emissies en mitigatie mogelijkheden met betrekking tot traditioneel biomassa-gebruik worden doorgaans niet in ogenschouw genomen. Er voltrekt zich een energietransitie in rurale gebieden, waarbij traditioneel biomassa-gebruik geleidelijk (en gedeeltelijk) wordt vervangen door commercieel energiegebruik. Ondanks deze transitie zal de totale energieconsumptie door rurale huishoudens (en de emissies die daarmee gepaard gaan) blijven stijgen indien de snelle ontwikkeling van de rurale economie blijft aanhouden. Het bevorderen van een transformatie in leveringssystemen en in het gedrag van rurale energiegebruikers is daarom van groot belang voor het vertragen en (wellicht) omkeren van dit proces.

Het ontwikkelen van hernieuwbare energie wordt gezien als een belangrijke strategie voor het optimaliseren van het leveringssysteem en voor het stimuleren van een koolstofarme transitie. Publieke acceptatie van dergelijke technologieën is belangrijk voor een succesvolle introductie en verspreiding. Hoofdstuk 3 past een sociaal-psychologisch raamwerk toe om de zienswijzen van rurale huishoudens omtrent een koolstofarme toekomst te analyseren d.m.v. het bestuderen van opvattingen over de ontwikkeling van hernieuwbare energie in ruraal China. Hiervoor is een case study onderzoek uitgevoerd in de provincie Shandong. De resultaten tonen aan dat de meeste rurale huishoudens slechts een vaag idee hebben van het concept 'low carbon' (koolstofarm). Desalniettemin spreken ze in het algemeen hun steun uit voor de ontwikkeling van hernieuwbare energie. Onder een groot deel van de respondenten is er een positieve gedragsintentie waar te nemen om te betalen voor de hogere kosten die de productie van hernieuwbare energie met zich meebrengt. Deze bereidheid om meer te betalen stijgt naarmate het inkomen van het huishouden en de kennis van het individu hoger zijn. Het ligt in de lijn der verwachtingen dat een verdergaande ontwikkeling van de rurale economie (en samenleving) zal resulteren in verbeteringen op het gebied van educatie en inkomens, en zal samengaan met een groeiend milieubewustzijn. Met het oog op de ontwikkeling van een koolstofarme samenleving kan dit verdere positieve veranderingen in energiepraktijken met zich meebrengen.

Er zijn grote verschillen in praktijken rond energiegebruik binnen ruraal China. Verschillende praktijken dragen in verschillende mate bij aan de uitstoot van broeikasgassen. Er is een case studie in Noord China (Shandong) uitgevoerd om deze verschillen in kaart te brengen en uit te zoeken welke factoren bepalend zijn voor energie gedragspraktijken (hoofdstuk 4). De uitkomsten tonen aan dat, in Noord China, ruimteverwarming de grootste bron van emissies is met een aandeel van circa 60% van huishoudelijke CO_2 emissies. De verschillen in gebruikspraktijken hebben ook tot gevolg dat er verschillende transitie-mogelijkheden zijn. De meest voor de hand liggende transitie omvat de modernisering van leefstijlen. Economische factoren zijn één van de belangrijkste drijfveren voor een dergelijke transitie. Waar groepen met een hoog inkomen blijken meer energie te consumeren voor transport en verwarming van water, gebruiken lage inkomens meer voor elementaire praktijken zoals ruimteverwarming en koken. Een transitie naar moderne(re) leefstijlen brengt doorgaans hogere CO_2 emissies met zich mee door een hogere vraag naar energie. Echter, tot op zekere hoogte vindt er ook een transitie naar een koolstofarme samenleving plaats binnen afzonderlijke praktijken. Zo wordt er bijvoorbeeld in toenemende mate aardgas in plaats van kolen of biomassa gebruikt voor het koken. Ook bij het opwarmen van water vervangt hernieuwbare energie, zoals zonne-energie of biogas, het gebruik van fossiele brandstoffen. Een koolstofarme ontwikkeling benadrukt zowel de modernisering als de ‘decarbonisatie’ (ontkoolstoffing) van energie-gebruikspraktijken, en kan dus niet los worden gezien van veranderingen in de energie voorziening.

De aanbod van rurale huisvesting is van groot belang voor toekomstig energieverbruik in ruraal China. In het afgelopen decennium is er een toenemende diversificatie van rurale huisvesting waar te nemen. Enerzijds zijn er verschillen in het type woningen, anderzijds zijn er verschillen in ´actor arrangements´ die het ontwerp van het huis, het type energie dat wordt gebruikt en dus ook het toekomstig energiegebruik in het huishouden bepalen. Er zijn een aantal case studies uitgevoerd naar geconcentreerde vormen van huisvesting in Shangdong en Binnen-Mongolië (China) om te begrijpen welke factoren koolstofarme huisvesting beïnvloeden (hoofdstuk 5). Het hoofddoel hier is om te begrijpen hoe beslissingen omtrent koolstofarme (gedrags- en technologische) alternatieven voor toekomstige energie gebruikspraktijken tot stand komen. De onderzoeksresultaten laten zien dat vooral aanbieders van huizen bepalen welke materialen, technologieën en energienetwerken toegepast worden in de ontwikkeling van rurale huisvesting. Geconcentreerde rurale huisvesting kan zowel de energie-efficiency van huizen als de leef-omstandigheden verbeteren vergeleken met traditionele (vrijstaande) vormen van huisvesting, met een relatief lage CO_2 uitstoot als gevolg. Lokale overheden, projectontwikkelaars in de private sector en lokale (energie-) autoriteiten hebben in principe de macht om koolstofarme alternatieven te kiezen en toe te passen. Maar ook andere energie-gerelateerde leveringssystemen zoals de commerciële energielevering, hernieuwbare energie opwekking en decentrale energielevering zijn betrokken bij de transitie. Tot op heden kan de transitie voor het grootste deel worden toegeschreven aan technologische verbeteringen binnen deze systemen. De transitie naar een koolstofarme samenleving zou echter ook sterk gebaat zijn bij andere verbeteringen, zoals een versterkte energiemarkt, decentraal management van energielevering, diversificatie van strategieën gericht op het betrekken van verschillende actoren, en een hogere graad van deelneming van rurale huishoudens (om het beeld van de 'captive consumer' bij te stellen).

In het kort: deze thesis laat zien dat de ontwikkeling en modernisering van rurale leefstijlen in China, en de toename in energiegebruik die daarmee gepaard gaat, tot een hogere uitstoot van broeikasgassen leidt. Praktijken rond energiegebruik in rurale huishoudens moeten zowel gemoderniseerd als gedecarboniseerd worden om deze uitstoot te verminderen. Enerzijds vereist dat een verbetering van het milieu-bewustzijn en de daaraan gekoppelde attitudes - dit moet ook in toenemende mate gaan meewegen in de besluitvorming omtrent energiegebruik in rurale huishoudens. Anderzijds vraagt het om een verdergaande diversificatie, modernisering en decarbonasatie van energie-gerelateerde leveringssystemen waarin koolstofarme alternatieven beschikbaar worden gemaakt voor rurale huishoudens.

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Name of the course	Department/ Institute	Year	ECTS (=28 hrs)
I. Project related competences			
Sociological Perspective on Environmental Change (ENP 32806)	WUR	2010	6
Advanced Environmental Economics and Policy (ENP 32306)	WUR	2010	6
From topic to thesis proposal (YRM 61303)	WUR	2010	3
Writing research proposal	WASS	2010	6
Advanced Econometrics (AEP 60306)	WUR	2012	6
SURE Project Workshop	WUR	2010-2011	2
II. General research related competences			
Doing Interpretative Analysis	WASS	2010	3
'Renewable energy use and local socio-economic development in China'	Sustainable Development of Energy, Water and Environment Systems, Croatia	2013	2
TOTAL			32

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