Straw Bale Construction in China
A comparison of obstacles between Northern and Southern rural areas for the use of Straw Bale Construction as an energy efficient building alternative

photo by *Kelly Lerner*

By

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ABSTRACT

In the 21st century, China faces the challenge of balancing the housing needs of its rapidly growing rural population and energy efficiency. Coal is the primary energy source for residential heating in rural and urban areas. Conventional buildings have very low capacities for insulation so heating from coal burning inefficiently escapes the walls of the house (Trexler 2002). Straw Bale Construction has considerably better heat preservation and has been shown to be a promising building alternative that meets housing needs and energy efficient goals of rural north of China.

Straw bale has high adaptability and is malleable enough to be use in rural residential development in the southern parts of China. However, personal and institutional barriers hinder the use of Straw Bale Construction from being incorporated into rural design. I interviewed principal parties involved in the straw bale projects in Northern China (not all data has been completely collected and analyzed at the time paper submitted) and analyzed regional statistics and also primary data compiled from 30 household interviews in the rural part of Southern China. Specific barriers to straw bale construction were detailed. Differences between the motivations and barriers to straw bale construction were found between rural Northern and Southern China.

INTRODUCTION

China is the most populous country in the world (Feld 2003). China's rapidly developing economy has a large impact on world energy market and the global environment (Hui 2000). The economics of the state identify the building industry as a vital engine of economic growth. The rising need of housing for the growing rural and urban population is a pressing issue. The Chinese government plans to increase spending on the development of new homes by or 15% or 97 billion dollars (China Housing 2000). Since China is likely to maintain rapid rates of

economic growth in the 21st century, a strategy for ensuring efficient use of energy is important for the sustainable development of housing to meet the needs of the rural and urban population.

China has the second highest total consumption of energy in the world. A large percentage of energy is use in the construction of buildings and use of coal for domestic heating in China (estimated 1.02 ton coal per capita).

As much as one-tenth of the total world economy is dedicated to the building and construction industry. One-sixth to one-half of the world's wood, minerals, water, and energy are used in the manufacturing and transport of construction materials. In terms of energy use, forty-five per cent of all the energy consumed in the world is used in the manufacturing and transportation of building and construction materials. This is more than all other uses combined, and is clearly unsustainable (World Watch Magazine). The building sector is responsible for a significant portion of China's total societal energy requirement. Future buildings in China are projected to consume approximately one-third of the world's total energy (Sustainable Urban Housing, 2000).

Meanwhile, China's dependence on coal also accounts for large portion of Chinese total energy consumption. The production and consumption of coal in China is the highest in the world (Finkelman et al. 1999; Feld 2003). In 2001, 1.49 billion short tons of coal was produced and 1.38 billion short tons were consumed, 26% world's total (Feld 2003). Coal is used for cooking and heating homes and its demand is projected to rise significantly in China. Total energy consumption in buildings is expected to grow nearly 6 percent every year - up to 199 million tons of standard coal in 2000 - far outstripping the anticipated growth in energy production of 2-4 percent per year (Energy Efficieny in Buildings). Coal burning releases substantial amount of greenhouse gases that affect global warming in the atmosphere (Florig 1997; Feld 2003; Pegg 2003). Coal burning also results in many adverse health effects such as,

arsenic, mercury, and selenium poisoning *(*Finkelman et al. 1999; Kleinerman et al. 2000; Pegg 2003).

The development of buildings and the use of coal in domestic heating are highly interlinked. Nearly 90 percent of the energy consumed in buildings is used for heating, yet a large proportion of that heat is wasted because of poorly designed homes and offices. China recognizes that the best way to meet the growing demand for coal fuel in buildings is to improve the energy efficiency of buildings.

Development reforms have encouraged the Chinese residential construction industry to move towards more energy efficient and environmentally friendly building materials (China Housing 2000). In many cases, the transition has opened the market for foreign building products. Construction has also involved movement from and even demolition and transformation of traditional building style and materials, which were thought to be inefficient and backwards. Contrary to popular perception, traditional architecture have been found to contain many sustainable elements as revealed by several recent studies on the Yao Dong dwellings China. The use of local materials, shading devices, natural ventilation for passive and evaporative cooling, steep roofs, thermal walls for passive heating are distinct characteristics of sustainability found in these earthen homes and other vernacular building styles (Wang et al. 1993; Fei et al. 2002; Jiaping et al. 2002; Zhou et al. 2002).

Straw Bale construction, a traditional type of building using agricultural waste product has been offered as an alternative means to reduce coal consumption for heating in rural areas. More than 22% of rural households rely on coal for domestic cooking and heating needs (Florig 1997; Finkelman et. al. 1999). Approximately 4 tons of carbon dioxide per year is release from each coal-burning rural conventional household in China. Reducing the rural population's dependency

of coal would be important part of sustainable development. The potential savings from the efficiency of straw bale construction in the populous rural would be huge.

Straw Bale construction as a form of sustainable development has been gaining popularity in rural part of Northern China. In 1999, Adventist Development and Relief Agency(ADRA) introduced straw building efforts to meet rising housing needs in rural China and curb energy use in rural China. The ADRA receives some of its funds from corporations from industrialized nations. Kyoto's Clean Development Mechanism (1997) allows corporations to benefit from investments in charitable projects that reduce CO_2 in lieu of curbing their own emissions. The collaboration among the US ADRA non-profit organization, Chinese local government and owners have resulted in successful construction of several straw bale houses in Inner Mongolia. In this region, winter temperatures routinely drop below freezing. Center for Environmentally Sound Technology Transfer (CESTT) studies demonstrate energy-efficient straw-bale insulation significantly reduces dependence on coal heating. (Han 2002; Trexler 2002). Straw bales have pockets of air between the strands of straw to better trap heat (Miller 2002). Straw bales resists the flow of heat two to three times better than conventional building materials (Magwood and Mack 2000).

Lastly, the production of straw bale is much more sustainable than conventional materials. Strawbales are at least thirty times less energy intensive than a wood frame or equivalent fiberglass insulation. It takes 120 thousand KJ of energy to produce a ton of straw and 6.15 million KJ to produce a ton of steel according to calculations performed by Richard Hoffmesiter at the Lloyd Wright School of architecture (2000).

Straw bale houses have a higher insulation value than traditional brick homes; thereby reducing the amount of coal needed for heating and subsequently, reducing CO_2 emissions.

Specifically, the average coal consumption in a SB household was reduce by 1-2 tons compared to average coal consumption in a conventional brick household (Han 2002). For each straw bale house in rural China, an estimated 125 tons of CO_2 emissions will be reduced over a span of 30 years (Han 2002; Wanek 2001). The success of the straw-bale program has led to their construction in three other northern provinces Jilin, Liao Ning, and Heilongjiang.

In rural China, there are over several hundred billion residents (China's Facts 2000; Population Distribution 2001). The implementation of straw bale technology for rural home building offers the opportunity to directly and considerably reduce the amount of coal used for heating in rural areas; thus reducing the consumption of energy consumption along with green house gases being released into the atmosphere.

Aside from curbing greenhouse gases, the use of straw bale in construction has an array of other benefits. New homes are economical and affordable. Higher moisture retention in straw-bale homes leads to a decrease in respiratory disease for residents (McRae 2000). Since straw is an agricultural waste, putting it to use in construction reduces the air pollution from field incineration. The use of straw bale as a building material also reduces the demand for wood; thus, reducing the pressure on China last remaining stands of forest. Housing needs can also be met in lieu of the logging ban.

The residential buildings in rural southern china also use coal for heating needs. Increasing energy efficiency in these urban buildings would have an equal, if not greater impact on energy conservation than rural buildings. The versatility of straw bales makes it just as feasible form of construction in the rural south areas. Despite the success of straw bale construction as an energy efficient development to meet housing needs in rural areas, rural construction in south remains unreceptive to innovative alternative as few or none straw bale structures are known to exist in

this region. Using economic accounting and analysis, my study will compare passive and active resistance to straw bale construction between the rural south and north areas and suggest ways in which straw bale stigma in these areas could be overcome.

OBJECTIVES

General Objectives

Through a comparative study, my project will identify and examine incentives and obstacles. I will then offer solutions for overcoming specific obstacles of straw bale construction in both rural northern and southern China.

Specific Objectives

1. Identify personal, economic, and institutional **factors** to straw bale construction.

-Differentiate between primary and secondary *factors*.

2. Identify personal, economic, and institutional **barriers** to straw bale construction.

-Differentiate between primary and secondary *barriers.*

-Who would be the active and passive opponents of straw bale construction?

3. Identify personal, economic, and institutional **incentives** to straw bale construction.

-Differentiate between primary and secondary *incentives*.

-Who would be the active and passive proponents of straw bale construction?

4. Identify general similarities and differences of incentives and barriers between rural Northern and Southern China.

5. Offer **solutions** for overcoming the obstacles found.

-Identify ways in which straw bale obstacles have been overcome and which one would be relevant to scenario in China.

-Create hierarchy of effectiveness for suggestions

-Discuss specific concrete ways in which resistance can be overcome in the context of specific rural location.

6. Other questions to consider:

-Are there miscellaneous factors?

-Are there any difficulties in categorizing the barriers and incentives into economic, personal, and institutional ? Do certain incentives and barriers fall under more than one category? How do personal, institutional, and economic interact and play off one another?

GENERAL METHODS

1. Comparative Economic Analysis will consist of intensive survey, collection, and in some cases calculation of governmental energy data records. Chinese bureau for economic policy and analysis will be an essential resource.

2. *Individual* Create and distribute survey (translated into Chinese) to owners of straw bale homes and other conventional homes to access priorities in a house (economics, conservation, comfort, type of material use, individuality, and finances). Conduct informant interviews with homeowners of straw bale housing. Anthropological participant-observation technique will also be used. I will go through a mock application process for the construction of a straw bale house in rural and urban China as an individual.

3. *Organization* Find and peruse building rules and regulations that pertain to Straw Bale construction in urban and rural areas concerning single owners and organization (sponsoring, architect, contractors). Conduct informant interviews of key American organizations/entities in the construction of rural straw bale homes (ADRA, Kelly Lerner, Chinese local organization). Examine economics and energy efficient housing goals of local governing bodies in terms of importance.

4. Examine the direct and indirect stakeholders in SBC and classify them as opponents or proponents accordingly. Conduct informant interviews and informational research for operating guidelines and philosophy of building inspectors, government officials, lenders, building supply yard employees, and surrounding community.

5. Look at the importance of antecedents, trend of regional consumerism and foreign influences, and demonstration homes in promoting Straw Bale Construction to target community. Through research and talking with architects, I will come up with ways in which opponents can become proponents.

Specific Extended Methods/Action Plan (Available Upon Request)

*also includes details of literature review, interviews, presentations, and statistical survey
*as well as detailing varying stages of execution, proposed, carried out, still in progress

HYPOTHESIS

Some barriers I predicted to find were personal misconceptions, financing, inexperienced institutions and builders, and building permits.

RESULTS

Personal

Incentives

The primary incentives for straw bale building in Alashlan, Inner Mongolia were affordability, conventional-looking house, and energy efficiency. The waste product straw and easy to build yourself nature reduces material costs and labor (costs 21000 RMB). A new, large brick house costs about 50,000 to 60,000 RMB (100 square feet). With ADRA's and local government subsidies, resettlers pay only 9000 RMB or about 1000 US. The insulating performance of straw bale walls are between R35 and R50 or almost three times the insulation of typical wood-frame wall system. Herders and farmers spend a good portion of their income on heating especially

during the winter month when temperature drop below freezing. The insulating capabilities of straw bale substantially reduce heating costs, as much as 50% (Lerner 2001). When 18 residents of straw bale homes were interviewed, everyone remarked on how much warmer the homes were using less coal. Straw bale design is malleable enough to incorporate brick features into the design so that homes have the same appearance as other houses in the neighborhood. Kelly Lerner found conforming appearance to be a huge selling point to the residents. Secondarily, straw bale houses are engineered to be more seismically stable in the earthquake risky region.

Barriers

In Tian Quan county, Yaan, Sichuan, when farmers were asked whether they would consider building with straw bale, 76% replied No and 24% replied Yes. Among those that stated they had no desire to construct with straw bale, 17% cited it was too primitive, another 33% justified lack of experience, 8% reasoned other, and 42% cited limitations of materials. Those who said lack of experience stated that they just didn't have enough knowledge, the technology required, or examples to follow. Concerns about limitations of straw bale included durability, stability, not being able to build a second floor or large structure, fire hazards, and strength. Others included a cultural preference for brick construction.

In Alashlan, Inner Mongolia, Kelly Lerner found similar barriers. People were concern about general issues with strength of straw bale, how it stood up to fire, moisture, etc. There was also a strong desire to have a house made of bricks and conformed to those of their neighbors. People also the notion/stigma of a straw bale house being too backwards and not desirable in modern times.

Institutional

Incentives

Overpopulation, intensive grazing and water use has resulted in massive desertification in Inner Mongolia. More than 300 families are relocated every year. Straw Bale homes is a environmentally viable solution that the local government can use to take care of the housing needs of those that are relocated. For foreign relief agencies, straw bale housing offers an effective means to alleviate poverty.

Barriers

In her experiences in Northern China, Lerner faced educational struggles with different institutions. Builders and contractors tended to be conservative. Many of contractors and builders prefer to keep within the practicality of tradition to minimize financial and structural errors. So, they were stubborn to the idea of building with straw bale.

Building codes and permits did not exist in the study sites and were not barriers contrasting with predictions. Similarly, insurance or appraisal was not an issue.

Economic

Incentives

*T*he prime economic incentive is environmentally affordable housing for people.

Barriers

Lerner recounted how financial disputes with the county government and contractors left the residents without electricity and running water.

Miscellaneous

Incentives

In Inner Mongolia, Kelly Lerner found that relationships among people or guan-xi help her get connected to builders, contractors, and officials.

CONCLUSIONS

In my findings, I had to add a separate category to of miscellaneous factors (Figure 1.5). This included the site-dependent availability and accessibility of straw. More importantly, it included the Chinese concept of guan-xi, “connections” or “relationships.” Many of the things that go on in China are govern more by guan xi or interactions between people than by rules. Although I put guan xi in a separate category, it should actually be better included in all the categories since guan xi operates or influences individuals, economics, and institutions. Since who you know and what types of relationships you have with those people could facilitate or hinder straw bale construction, it would be key to identify the opponents and supporters. I imagine the main allies for straw bale construction are natural builders and architects, those who have experience building with straw bale, residents living in straw bale houses, trained and educated local builders and contractors. The opponents may be conservatives who are resistant to new ideas and concrete and brick construction companies.

Using collaborated efforts, subsidies, community trainings, and established antecedents, straw bale construction in Inner Mongolia met success. Perhaps these same tools could be use to overcome the barriers in the south and other northern parts of China. Joint efforts contributed to the success of straw bale construction in the Northern China because different organizations can hold one another accountable. For the relocated herders that were being relocated, government subsidies along with funding from different agencies were integral in providing the financial resources to build the new houses. Lerner found out that community trainings were useful to show slides of straw bale houses and address people’s concerns about fire, moisture, and pests. Nevertheless, I found having examples of straw bale houses in the vicinity of proposed construction to be the most effective ways of changing institutional, governmental, and personal

stigma. The established antecedents allow them to experience, to look, see, touch, …engage people's senses and then dispel their concerns about uncommon building material. Through the use of a variety of educational tools, nayers could be enlightened into sayers.

Additionally, experiences of those building with straw bale appear quite varied. Although common barriers and incentives exist, there are also various degree of appeal for straw bale in the north and south. There appears to be greater levels of appeal in Alashlan, Inner Mongolia for straw bale is relocated herders in need of affordable housing, seismically strong in earthquake risky environment, and energy efficient (reducing heating costs). In Tian Quan County, Sichuan, there are only a few cold months of the year (heating is not a major issue), no earthquake problems, etc. so benefits from straw bale may be fewer. Furthermore, at least in Tian Quan, I did not see an abundance of straw resources. However, as an adaptable and stable house in hot wet environment, straw bale still has its benefits in Tian Quan for those seeking an affordable alternative to wood, concrete, and brick structures. The high thermal resistance of straw bale that keeps houses warmer in the winter also keeps houses cooler in the summer. In turn, less fossil fuels or burns and energy use is reduced, and less pollutants are released.

FURTHER STUDIES

1) Follow up with people living in recently built compared with longer residents of straw bale houses in Northern China

2) Building a straw bale structure in Tian Quan County, Sichuan and studying people's perceptions through the progress of the project depending on varying degrees of involvement

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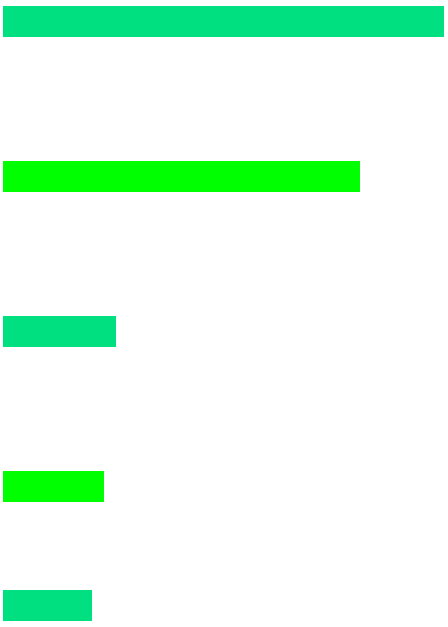
APPENDIX

Figure 1.1 Table and Graph for China's coal consumption amount top 5 countries

	Country	Description	Amount of Coal Consumption
1.	China	1.31 billion short tons (2000E)	
2.	United States	1,060 million short tons (2001E)	
3.	India	339 million short tons (2001E)	
4.	Russia	298 million short tons (2000E)	
5.	Germany	265 million short tons	



	(2001E)
Total	3.27 billion
Average	654.4 million

Figure 1.2 Study Sites in China

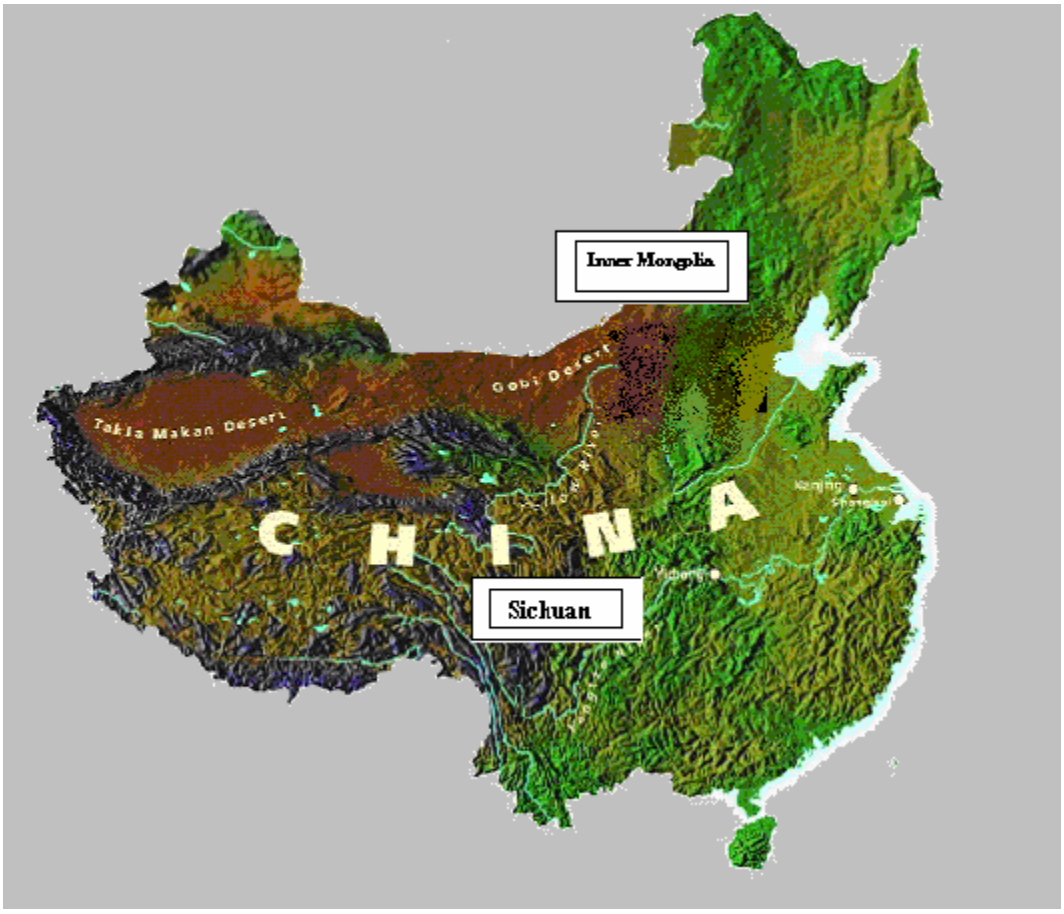


Figure 1.3 Inner Mongolia, China. Photos straw bale in-fills (source: Lerner, K)

Figure 1.4 Inner Mongolia, China. Workers stacking bale walls (Lerner, K)

Figure 1.5 Categorized factors and personal, economic, and institutional barriers and incentives outline chart to Straw Bale Construction in China

Categories and Factors	**Incentives +**	**Disincentives -**
Personal Awareness Perceptions Financial situation Family's influence Multiple owners (family stakes	Precedents (traditional, recent construction to allow others to experience) -Good experience with previous straw use in house -Better indoor air quality	Stigma (backwards) Brick to Brick Dreams Concerns (fire, stability, moisture) -Bad experience with previous straw use in house

vs individual stakes) Religion/myths/superstitions	-affortability	
Economic Lenders Housing Needs Population distribution	Resource Abundance (source of straw) Energy Efficiency Reduce Coal consumption Housing need	Resistant Lender
Institutional/Political Local Investment Foreign Investment (effort/money) Permits Policy	Government Subsidies	
Miscellaneous **-Guan Xi**	**ASDRA-foreign charity organization** **-Avaliability of straw** **-investors**	

Figure 1.6 (Raw Survey Data, unattached)

Figure 1.7. Southern Households Consider Building with Straw Bale Findings

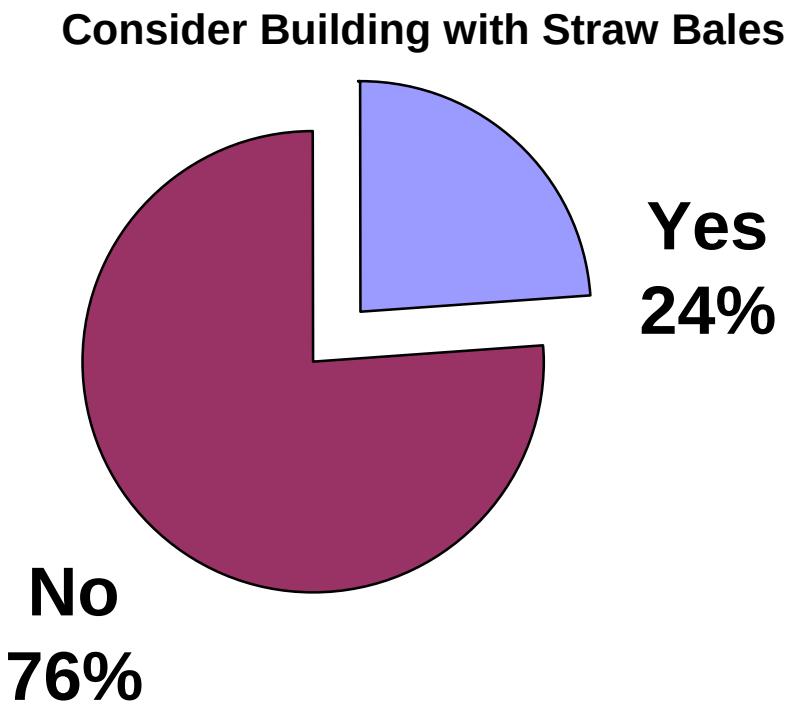


Figure 1.8 Reasons for Not Desiring to Build with Straw Bale Construction

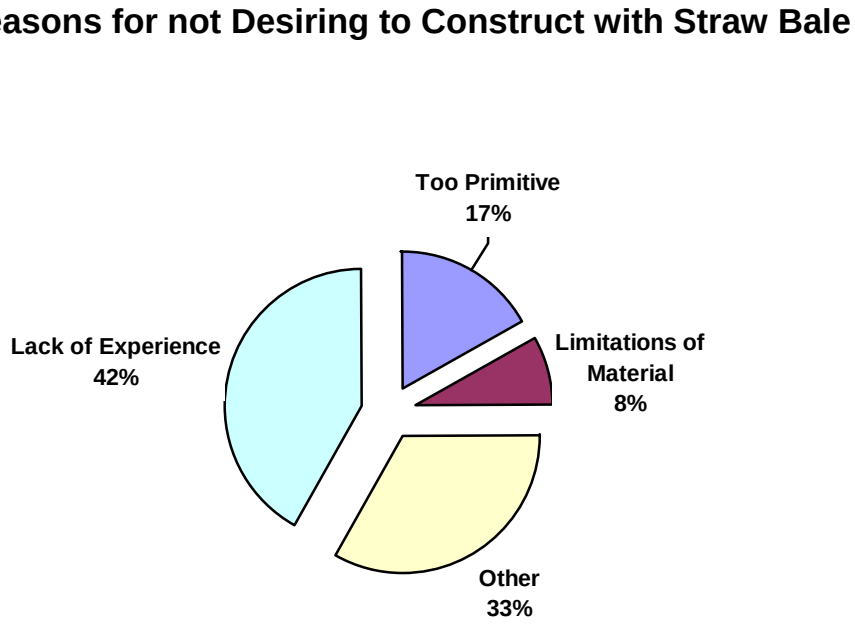


Figure 1.8 Survey Questions Rural Household Tian Quan, Sichuan

* Questions incorporated into survey used

*What type of materials would you prefer to use to build your house?

What kind of house do you want to live in?

*Have you ever build your own home before? If so, what type of materials are you familiar with?

*How big is your house (square footage, units)?

*How much did you spend on your house?

*What is your income?

*What sources of energy do you draw your heat from (Coal, fuelwood, dung, electricity)?

*Whish is your main source (What %)?

*How much coal do you use (amt, %)?

*How much do you spend on heating?

What percent of that is your income?

What main factors do you take into consideration when building or buying a home? Name at least 3 factors in order of importance (greatest to least)?

How important is energy efficiency to your decision (Scale 1-5)?

*Are you familiar with building with straw bale?

*Would you live in a straw bale house if it was more energy efficient (need less energy to heat), looks like a normal home, stable, and saves money?

How important are government subsidies in building a home (1-5)?

Figure 1.9 Wheat straw field in Shandong (left) Rice straw field in Guan Xi(right) (by Vuong,L)

Figure 1.10 Inner Mongolia cob-straw house (by Vuong, L)

Figure 1.11 Straw Bale Construction photos (by Lerner, K)

Figure 1.12 Farmer Interview photos (Vuong, L)