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Promotion of Bioenergy in Rural China
From the Business Perspective

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Abstract

This research investigates the current situation of bioenergy development in rural China from the business perspective. Biomass combustion power stations, medium and large biogas facilities, and household level biogas digesters are discussed in the research. In total 6 empirical case studies and interviews with different stakeholders are employed in the research. This thesis argues that the government-oriented bioenergy promotion strategy is not the most cost-effective way to stimulate the whole industry. This thesis points out that the current predicament of bioenergy demonstration projects is due to technology adaptability problems, the sharply increasing price of raw materials and high transaction costs during the collection stage. Besides, high initial costs and the lack of financing channels also delay the large-scale commercialization and dissemination of bioenergy technologies in rural China. This thesis also finds that local economic conditions, as well as the cultural and social context, are critical factors for the success of bioenergy development in rural China. This thesis suggests that energy service models and local professional co-operatives are effective in helping local residents be involved in the market economy, and in building trust between local residents, energy companies and the operation of bioenergy projects. Four recommendations are made: (1) conduct a biomass resource investigation under market conditions and the local social and cultural situations; (2) ensure strict regulation of the number and capacity of large biomass power stations; (3) bring about modification of the current subsidy system and include coal-firing technology under the subsidy; and (4) promote professional co-operatives and energy service company models in rural China.

Executive Summary

For a long time period in China, bioenergy – particularly the household biogas digester system – has been promoted for the purpose of reducing poverty, improving human welfare and raising living standards, mainly by the national government. However, it does not lead to the most cost-effective outcomes in terms of investment, and fails to support the large-scale dissemination of bioenergy technologies in rural China (Gan 2008). Instead, private companies have already demonstrated the important opportunity to scale up bioenergy in rural China, if approached properly. Besides, an ambitious bioenergy development target has been set in China's "11th Five-Year Plan", and can hardly be achieved without commercialization and dissemination of bioenergy technologies in rural China. Therefore, it is extremely important to investigate the biomass utilization business and its emerging market in rural China, to analyze opportunities for and barriers to the business and market, and to summarize successful models which can be diffused and replicated.

In order to achieve these research aims, 6 cases are employed to investigate three major technologies in rural China. These cases include: the Shanxian biomass power station case, the Mishan biogas generation and energy service company case, the Taihua biogas generation and rural cooperative case, the Shenlong biogas and carbon credit generation case, the Hangzhou energy service company case, and the Global Environmental Institute (GEI) household biogas digester and rural cooperative case. The Shanxian Case focuses on the barriers to and the solutions for biomass power stations in rural China. The Mishan, Taihua and Shenlong cases discuss the opportunities, barriers and solutions to replicate medium and large scale biogas projects in rural China. The Hangzhou case pays great attention to the application of the energy service model on biogas projects, and the GEI case provides a good example of how to organize local residents and help them become involved in the market economy based on a biogas cooperative.

This thesis consists of 5 chapters. Chapter 1 summarizes the general situation of bioenergy development in rural China, and describes the research aims and questions based on this summary. Chapter 2 is about the methodology and implementation plan of this research. Chapter 3 presents the 6 case studies and related empirical data and information from interviews. Chapter 4 is the analysis and discussion part of the case studies. The last chapter summarizes the research implications and provides further recommendations for policy-making and business strategy.

Social and cultural acceptance is an important criterion for bioenergy businesses in rural China. For biomass power stations, local people are the main suppliers of the biomass resource. The transaction costs for resource collection are highly reliant upon the local network and the trust of millions of individual local resource suppliers. For biogas facilities, local people are usually the main consumers of the biogas and their consensus also relies on trust. Besides, a business contract is not as important as personal beliefs in many rural areas, due to cultural and social factors. This requires the establishment of trust between the local community and the external energy companies before the process of bioenergy projects begins.

Most biomass combustion projects are not profitable. The sharp increase of biomass resource prices makes it hard to obtain benefits during the operation period. Biomass resource supply cannot match demand at current price levels and this leads to a big risk for the operation of projects. The existing renewable energy subsidy offers substantial

help for these demonstration projects, but is still insufficient. Besides, high initial investment is the bottleneck for the private sector to enter this field; the main reasons are high technology import costs as well as applicability costs due to equipment maintenance. Grid connection is another challenge for on-grid power projects due to both technical and economic issues. Off-grid power projects usually cannot be financed by the government and have to search for other external investment – often unsuccessfully.

For medium and larger biogas projects, the current waste-to-energy industry faces a dilemma: the best technology is not the preferable choice for developers, who are mostly livestock farm owners. Due to high initial costs, they do not want to spend extra money on energy facilities which are not closely related to their main task. The Energy Service Company (ESCO) model can help solve these problems. The ESCO can invest in biogas facilities, provide for servicing and share in the benefits from the waste treatment. Financing the ESCO model is also a problem due to uncertainty and high risk in this new industry. Primary movers can motivate the whole industry; venture capital also plays an important role in this field.

The professional rural co-operative is a good model to help local people to be involved in the market economy. The co-operative has proved to be helpful to promote household biogas digesters. Local residents share construction labour, maintenance costs and the cost of technicians; this helps to reduce the total cost and make the technology more socially and culturally acceptable. This is also valuable for biomass collection. Private companies lack the capacity to organize local people and help them become involved in the market economy. Local residents cannot achieve market involvement by themselves; a third party (like the Professional Co-operative, NGOs or brokers) can play an important role in reaching this goal.

Finally, for more cost-effective regulations and authority, the national government needs to organize an investigation into biomass resources as soon as possible. Economic indicators, market conditions and local social and cultural factors should all be taken into account in the investigation. Modification of the national strategy and related regulations should be made according to the results of the investigation. Furthermore, the temporal subsidy needs to be more accessible to primary investors in the project planning stage. Coal-firing stations could also be included in the subsidy system, with the necessary monitoring methodology.

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1. Introduction and Background

1.1 Context

Biomass is an important resource for the mitigation of climate change, enhancing energy security and promoting sustainable development in rural areas. This is extremely true in China where 70% of the population live in rural areas and have a long history of relying on biomass for heating and cooking. It is no wonder then, as claimed by the National Development and Reform Commission of China (NDRC 2007a), that biomass is a crucial renewable energy resource for a sustainable future for rural China.

For a long time bioenergy has been promoted mainly through the national government. It have been broadly discussed recently that investment from only the government is not enough (Li et al. 2001, Liao et al. 2003). Furthermore, according to Prahalad and Hart's theory of the Base of the Pyramid, business in rural and less developed areas can be a great opportunity for an untapped trillion dollar market if approached properly. This opportunity is especially important for China under the current economic recession situation to shift from an export-oriented economy to a more sustainable pathway of development which relies more on domestic demand.

In practice, unlike other renewable energy projects such as wind, hydro and solar energy which are mostly run by state-owned companies, bioenergy projects are usually in small or medium sizes which are much easier to start by private investments. In fact, the bioenergy industry in China is indeed stimulated by private investment in bio-diesel generation from swill, and this provides many good experiences (Hu 2005). Moreover, there are already some micro-financial service institutions in rural China which can provide certain support on the local level. Hence there is a great potential to further develop bioenergy in rural China with sound business models.

From the governmental perspective, there are several crucial principles of bioenergy development promoted by the Chinese national government. These include: it should not conflict with food, it should not compete with traditional industries and there should be few distracts from by the international resource market. Meanwhile it should also be incorporable with the sustainable development of rural areas and contribute to poverty alleviation (Niu 2008). Furthermore, an ambitious bioenergy development target for rural China has been made in the "11th Five-Year Plan" of China: 40 million households will have methane-generating pits; the number of medium and large-scale biogas projects will be increased to 6300 with the annual output of gas reaching 190b cubic meters (including 4700 livestock methane projects with a total annual output of methane gas of 150b cubic meters); increasing using solid biomass fuel from agriculture and forestry to 1m tons; increasing bioethanol and biodiesel production from non-grain raw materials to 2 million tons; and the national installed capacity of biomass power generation is expected to reach 5,5m kilowatt (NDRC 2007a). Therefore, this study is extremely important given the recent situation where China has announced its multi-billion-dollar economic stimulation package which includes investments in energy and rural development.

1.2 Biomass Utilization in China

1.2.1 Biomass Resource

Biomass resources are currently utilized through four categories in China: (1) agriculture and forestry residues; (2) manure from livestock farms and rural households; (3) municipal waste including waste cooking oil; (4) and energy plantations (Li et al., 2001).

1.2.1.1 Agricultural residues

Agricultural residues mainly refer to straw, stalks and husk of crops. In China, main crops include rice, wheat, corn, beans, tubers, sorghum, coarse grains, oil bearing crops, cotton and sugarcane (Li et al., 2005). Presently, the usage of agricultural residues include cooking and heating in rural households, fertilizer, forage and raw material of paper (Li et al., 2005). The forest residues are usually categorized into this type especially in agriculture areas. They come from fuelwood and waste of forest industries which are widely available in rural China but with unbalanced distribution (Li et al., 2001).

Agricultural residues can be identified as two types. Primary residues are the biomass generates during the harvest site (e.g. rice straw, sugar cane tops) which are usually used as fertilizer or animal feed and hard to collection (Bhattacharya, 2005). Comparably, secondary residues refer to the co-produced residues during the further processing after harvest such as rice husk and bagasse. Relatively large quantities of secondary residues are easily to get at the processing site without further transportation and handling cost (Li et al., 2005) and thereby are considered as a suitable biomass resource for commercial purpose of energy generation. Energy potential from agriculture is expected to be 5.31 EJ (Bhattacharya et al, 2005) in 2010. But few data is available about distribution between primary and secondary residues and further work is required here.

1.2.1.2 Distribution of agricultural residues

In general, agricultural residues is widely available around China but with unbalanced distribution among regions (Li et al. 2001). East and Middle-south China have the largest portion of total production while Northeast China has the highest per capita production. For energy purpose, a three-stage calculation model has been developed by NDRC (2008), the total production, the accessible amount and the energy potential. According to NDCR's data of 2005, 0.3 billion tons of agricultural residues can be used for energy purpose which is equal to 0.15 billion tons standard coal.

Table 1-1 The regional distribution of agricultural residues in China

Region	*Total*	*Per capita*	*Typical provinces*
North China	**6540.1**	**0.79**	**Shanxi, Hebei**
Northeast China	**7638.0**	**1.63**	**Jilin, Liaoning**
Middle -south China	**12324.8**	**0.50**	**Hubei, Hunan**
East China	**12998.7**	**0.56**	**Shandong, Jiangsu**
Southwest China	**6289.7**	**0.48**	**Sichuan, Yunnan**
Northwest China	**3974.5**	**0.75**	**Gansu, Qinghai**

Source: NDRC 2008

The residues potential for energy purpose of different provinces are list below. Agriculture is the dominant economic activity in North China provinces like Shandong and Hebei, Middle-south China provinces like Henan and Northeast China. There is a great potential to utilize biomass in these regions.

Table 1-2 The potential of agricultural residues for energy purpose in different province

Region	Agricultural residues available for energy (Thousand ton)	Order	Region	Forest residues available for energy (Thousand ton)	Order
Shandong	44,070	1	Heilongjiang	29,486	1
Henan	30,637	2	Inner mongolia	26,049	2
Hebei	29,549	3	Sichuan	24,624	3
Jiangsu	27,949	4	Yunnan	20,874	4
Heilongjiang	26,372	5	Jilin	11,200	5
Jilin	24,079	6	Jiangxi	10,676	6
Sichuan	21,632	7	Hunan	9517	7
Hubei	16,894	8	Guangxi	9264	8
Anhui	15,790	9	Guangdong	9219	9
Inner Mongolia	15,739	10	Shanxi	8927	10

Source: Liao et al. 2004

1.2.1.3 Livestock manure

Livestock manure refers to animal dung and wastes which has been used for centuries as a fertilizer for farming. According to REDP (2005), nearly 80 billion cubic meters of biogas, which equals 57 million tons of standard coal equivalent are generated from farming and agriculture industry in China (Li et al., 2001).

Animal manure from large and medium-sized farms have a great potential for commercial energy utilization. Compare to small-sized or household farming, manure from large or medium-sized farms which cattle, pigs and poultry are generally raised in pens are easily to collected and used on site for energy purpose. Due to the demand side increasing, around 6000 large or medium-sized farms are established in China recently. But only 20% of excrement and foul water is treated properly while only 10% of this is processed through bioenergy technology (Li et al., 2005). The general potential of bioenergy from animal manures is expected to increase from 11 EJ (1997) to 2.1 EJ (2010) (Li et al., 2005). However, few studies are going to further to the large and medium-sized farms and the possible technology for them.

1.2.1.4 Municipal and industrial waste

The MSW in China has increased at a rate of 8% -10% in recent years (Zhang & Ling, 2003) due to the fast growth of economics. It is expected by REDP project (2005) that 210 million tons of MSW can be used in 2020 for methane production. Recently, the use of waste oil for biodiesel is very popular especially in South China. However, lacking of accessible resources significantly blocks the further development of the biodiesel industry. Meanwhile, some other ways of using MSW for energy were analyzed in 2005 (Li et al., 2005) and using MSW for LFG was considered as with great potential.

Both solid waste and wastewater from certain industries (sugar, alcohol, starch, food, oils, medicine, paper et al) with a high concentration of organic materials can be considered as a potential bioenergy resource with the anaerobic treatment system. Total CH4 generation potential is estimated t to 102 PJ in 2010 (Li et al., 2005). Due to the strict standards and high costs of discharge of waste into the civil system, the willing of industries to develop anaerobic treatment system is expected to be increasing in the next few years and thereby there is a great potential to promote this market.

1.2.1.5 Biofuels

Commercial plants for bioethanol were promoted by the national government of China during its 10th five year plan as demonstration projects. In the National Energy Plantation Development Plan (2006-2010), national Forestry Administration has emphasized a certain key species, Jatrophacurcasl., Pistacia chinesis Bunge, Cornus Wilsoniana Wanaer, Xanthoceras sorbifolia Bunge as potential for further development (SFA, 2006). Biodiesel and bioethanol companies also show interests to invest in energy plantations for raw material supply. However, there is a strong tension between food supply and energy plantations.

1.2.1.6 Energy efficiency

Bioenergy potential through energy efficiency in rural areas is also considered as a resource. In developing countries like China, biomass plays important role in meeting the rural domestic energy consumption for cooking and heating. However, most of the methods of using biomass are still following traditional ways which are "inefficient". For example, the stove connected with bed system is China has efficiency of 20-30% but is broadly used among 177 million households (Li et al., 2005). So there is a great potential of saving the amount of biomass through efficiency improvement which can be considered as a source for additional energy and can potentially substitute for fossil fuels. Research should further be done from both technologic and social-economic perspective.

1.2.2 Conventional Utilization of Biomass

Biomass (mainly crop straw) is an important part of the rural energy and is still widely used for cooking and heating in rural areas. For example in Hunan Province which is a typical agriculture province in middle China, 46% of rural households are still rely on straw and residues for cooking and heating with a consumption of 23.58% of the total amount of biomass resource in Hunan Province. Especially in some agriculture and remote areas, more than 60% of household energy consumption comes from conventional utilization of biomass (Sino-Danish Project, 2008).

In the conventional household agriculture system, straw is usually used as fertilizer to return to field in the no-agriculture seasons. Also, a large portion of straw was burnt directly and the dust after burning is used as a fertilizer. It is forbidden to burn straw without control due to the air pollution. However, 14.1% of the total biomass is still used as fertilizer in Hunan Province which is a common situation in rural China (Sino-Danish Project, 2008). In practice, straw has many environmental benefits as fertilizer comparing to chemical fertilizers.

As straw is full of cellulose, hemi-cellulose and lignose, it is an important feed resource for livestock industry. For example, in rural China, paddy haulm is widely used as a feed for farm cattle, and rice hull is processed into bran cakes to feed pig or fish. Even though modern fodder industry has largely decrease the use of straw in feeding, it still account for 23.97% of total biomass (Sino-Danish Project, 2008).

Also, straw is an important raw material for paper industry and this account for 2.52%.of the total amount of biomass. So in Hunan case, 34.93% of the remaining straw (10.8

million tons) can be used as commercialized biomass resources (Sino-Danish Project, 2008).

1.2.3 Biomass Modern Utilization

1.2.3.1 Biomass direct combustion and power generation

The biomass direct combustion and power generation process refer to the direct combustion of biomass to provide heat which is used to raise the temperature of water or convert it into steam. This water water/steam can be used to drive steam turbine to generate electricity (Ralph. 2002). The main technical process is described in the following figure.

Figure 1-1 The direct biomass combustion for power generation

Source: Ralph Sims 2002

Boiler is the crucial part of the process. The design of boiler can be either fixed-bed or fluidized-bed. For fixed-bed, three methods are used to feed the fuel onto the grate which are travelling grate stokers, spreader stokers and sloping-grate furnace (Ralph. 2002). There are two types of boilers used in demonstration projects in China. The first type is Circulating Fluidized-bed boiler developed by Wuxi Huangguang Boiler C.,Ltd. which is a state-owned listed company in China. The boiler has been installed in Hebei Jinzhou Biomass Power Station. The second type is Water Cooled Vibration Grate Firing boiler which is a type of fixed-bed boiler. The technology is introduced by Dragon Power C.,Ltd (DP). from a Danish company Burmeister & Wain Energy (BWE) which is a leading bioenergy manufacture producer in the world. The boiler has been used in more than 8 demonstration projects invested by DP.

The low energy density is the main problem in boiler handling. Besides, some biomass contains a significant portion of inorganic constituents such as chlorine, sulfur and potassium. These salts like KCl and K2SO4 are quite volatile which usually leads to deposition on surface of heat exchangers and the enhancement of corrosion rates. It also cause the generation of significant amounts of aerosols with relatively high emissions of HCl and SO2 (EBIA 2009). In China, the concentrations of inorganic constituents are different among different areas due to the variation of products, soil and fertilizer. But in generation, the situation is much worse comparing to Nordic countries where the mainstream technologies are introduced from due to the use of high-dose chemical fertilizer and pesticides (Qing, Xu pers.comm).

According to the China' national Medium and Long Term Development Planning of Renewable Energy (2007), the installation of biomass power generation capacity is expected to be 5.5 million KW in 2010 and 30 million KW by 2020. Stimulated by this national strategy and related subsidy policies, 82 biomass direct combustion power generation projects had been approved till the end of 2007, of which 14 projects have already been in operation, and about 30 projects are under construction currently (Sino-Danish Biomass Energy Project, 2008).

1.2.3.2 Biomass gasification

Biomass Gasification refers to the conversion of solid biomass into a gaseous thermo-chemically. The gaseous are then used in gas turbine or gas engine for electricity generator (Ralph. 2002). There are four common types of gasifier design and reaction zones: counter-current moving bed, co-current moving bed, cross-current moving bed and fluidized bed (Ralph. 2002). Comparing to the direct combustion with an overall conversion efficiency of only 15-18%, the gasification system can achieve an efficiency of around 35% (Ralph. 2002). The installation capacity of biomass gasification station is usually between 4-10 MW. The main technical process is described in the following figure.

Figure 1-2 The biomass gasification for power generation

Source: Ralph Sims 2003, the graph is made in the research

The gasification system is much more suitable for China (NDRC, 2008). First, initial investment is much smaller than combustion power station. Second, the biomass demand is around 30000 tons per year (4 MW) which can be easily achieved in rural China with a suitable price. Third, operation cost is much lower (NDRC, 2008).

In China, more than 30 off-grid biomass gasification stations have been built since 1998. Most of these projects use the circulating fluidized bed gasification technology which is developed by Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences (GIEC-CAS) with the capacity of no more than 1 MW. The only ongoing on-grid biomass gasification station is located in Jiangsu Province with a capacity of 5.5 MW.

1.2.3.3 Biochemical conversion and biogas generation

Anaerobic digestion is the commonest biochemical process used to convert waste biomass resource to bioenergy which are normally biogas or landfill gas (Ralph. 2002). The energy resource is organic waste materials (like livestock manure and landfill waste). The process is considered as a waste-to-energy solution with many benefits such as the odor and pollution control, biogas for energy and residues for fertilizers (Ralph. 2002). In China, large-medium scale biogas plants have been highly promoted in rural China after 2008. Besides the benefits mentioned above, the plants can provide job opportunities in rural areas, enhance the living standards and increase the income of local villagers (NDRC 2008). Most of the ongoing projects are large or medium size animal manure treatment plants or straw anaerobic treatment facilities.

Biogas can be used for agricultural (drying or livestock production heating) and domestic purpose (house heating and cooking). However, matching the biogas utilization to energy demand side is the main challenge in the operation of the project. Both demand and production ratio are highly variable in different seasons, especially in summer when more biogas is generated while less is needed (Ralph. 2002). Biogas can be also used by off-grid generator to provide electricity for on-site use. It is not economically viable to export electricity to the grid but on-site utilization can save the retail purchase costs (Ralph.

2002, Xiong pers.comm). Landfill gas is also considered as this type and is normally used for power generation.

In China, "medium and large scale biogas project" is strongly promoted by government after year 2007. The project includes raw materials pre-treatment, utilization of biogas, and the utilization and treatment of residues. The definition and category of different scale of biogas projects are listed below.

Table 1-3 The category of biogas project in China

Scale	Volume of single digester (m3)	Total volume (m3)	Daily gas production (m3/D)
Large	>500	>1000	>1,000
Medium	50-500	50-1,000	50-1,000
Small	<50	<50	<50

Source: Qin, 2007

1.2.3.4 Co-firing of biomass

Co-firing of biomass is to involve burning biomass together with the conventional fossils (Ralph. 2002). It can be achieved by the transformation of conventional coal power station. The cost of transformation is much cheaper and more efficient than the construction of new biomass facilities. The technology itself is also mature and it is a promising technology for the immediate increase usage of biomass (Ralph. 2002). Also, since the co-firing ratio can be controlled in a broad range, it can also help to reduce the risk of resource supply variation and help to maintain the stability of biomass price in China. However, due to the monitor problems, it is not included in the renewable energy law and can hardly get renewable subsidy. Due to this policy barrier, the development of co-firing has been significantly delayed (NDRC 2008). The only co-firing project as a renewable energy power station is the Shiliquan station in Shandong Province. The subsidy is guaranteed by provincial grid as 0.24 Yuan/kWh. Shanghai Xiejin Power Company also uses this technology in 7 stations but without subsidy.

1.2.3.5 Household level biogas digester

China has spent great efforts in the past thirty years on the rural household biogas digester through government subsidies. 70 million rural population have been benefited from the promotion of biogas digesters (Gan & Yu, 2008). Subsidy goes directly from the Ministry of Agriculture to regional government. Together with the co-finance arrangement from regional and local government, there is around 5 billion Yuan each year goes mainly to the western China to help the construction of biodigester promotion. However, this subsidy is not considered as cost-effectiveness. First, local people are lack of capacity to maintain the facility or they do not want to maintain it carefully due to the complexity. Second, the money goes on the period based and there is no continuously support for local energy stations to monitor the whole facilities. Third, it delays the commercialization of biogas digester especially the high quality technology because almost all rural people do not want to spend their own money on building digesters. Even though there are a lot of problems, the household biogas digester is still strongly promoted by national government, for the benefits of dealing indoor air pollution and poverty reduction. Also, innovative finance mechanisms such as micro-finance to local residents and local private energy service companies are also demonstrated in rural China (Gan & Yu, 2008).

1.2.3.6 Other technologies

Combined heat and power (CHP) is also under discussion as a possible technology of biomass utilization. The main purpose is to use the heat released in the electricity generation process for community level heating (Ralph. 2002). CHP can help increase energy efficiency significantly in the conventional power stations. However, community heating system requires the stability of the operation. In China, the biomass utilization is still in the demonstration level and resource supply is highly variable which makes it hard to maintain the continuously operation of the boiler. So biomass CHP project is still under discussion.

Biomass solidification is also used in rural China. The technique is to increase the density of biomass materials 5-6 times through physical press. During the solidification process, it kills the insect pests in materials and gets rid of the rotten part so as to make biomass fuel have a uniform texture and trimmed appearance. A single machine can produce biomass solidification fuel in a small scale.

1.2.4 Renewable energy law and other government regulations

The renewable energy law and related national and regional level regulations, especially the electricity price determining regulations, play an important role in the development of bioenergy in rural China. Key elements related to the commercialization and market operations are discussed here.

1.2.4.1 Principles

Renewable Energy Law of the PRC (hereinafter called Renewable Energy Law) was passed on February 28, 2005 and executed since January 1, 2006. The aim is to promote the renewable energy development with the combination of national responsibilities and civil obligations. Following this, five principles have been well defined in the law which are: total target, compulsory grid connection, categorized electricity price, expense re-allocation, and specific funding. Coming into details, national renewable energy target should be made by central government. National and provincial renewable energy resources development planning should be made by related departments. Price of electricity generated from renewables should be made by national government and grid companies should purchase all electricity from renewables based on the biding price compulsorily. The excessive cost due to compulsory grid connection and purchase should be shared among customers in the grid. The money collected from terminal customers should be organized as a specific fund to compensate the extra costs of the grid. Some key issues will be further discussed below.

1.2.4.2 National plan and targets

On-grid biomass power station especially the station with a capacity more than 10 MW is clearly identified in the Renewable Energy Law that will be promoted in future. Besides, decentralized energy system should be promoted in remote or proper areas where the national power grid cannot easily or efficiently cover. This gives the permission to build off-grid power facilities in rural areas (for example, biomass power station to utilize biomass or livestock waste for on-site use).

1.2.4.3 Pricing determining mechanism for on-grid electricity

It is specified in the NDRC's "Proposed Management Methods for the Renewable Energy Power Generation Price and Expense Allocation" that the price of electricity from biomass power station should comprise of the average grid price of the desulfurization fuel station of the year 2005 in each province plus a renewable energy price subsidy which is CNY 0.25 per kilowatt hour. The source of the subsidy is shared among customers in the grid as "added power price for renewable energy". The subsidy is 15 year period based with a decrease of 2% each year. Besides, it is strictly regulated that the hybrid-fuel power station with exceeding of 20% of fossil fuels should be deemed as a regular energy power generation station with no subsidy provided by government. In practice, as to maintain the operation of the renewable energy projects especially those demonstration projects which are in deficit even with the subsidy, a temporary subsidy is usually provided by province level government. Besides, co-firing station with a more than 20% of fossil fuels should not be considered as renewable energy. This is strictly to the waste incinerator stations where fossil fuels are always added to maintain the stable temperature of the boiler.

1.2.4.4 Grid connection of renewable projects

It is specified in the Renewable Energy Law that the grid company should "provide grid-connection service" to "large and medium renewable energy power generation projects" such as biomass power stations to purchase the power from renewables. The grid company should be in charge of the grid connection system and should invest on the construction of the system. This provides the legal guarantee for the sale of power from biomass power generation project. The grid connection costs should also be allocated into the electricity price and shared among final customers. The grid company should be liable for compensation of the loss if they cannot or fail to purchase all electricity from the renewable power station, a fine can also be employed to enforce the grid company to purchase electricity from renewable power stations. However, it is not compulsory in practice that the grid company should be in charge of the grid connection for all stations due to the high costs and technical complexity.

1.2.4.5 Administration and regulation of renewable energy projects

It is defined in the administration regulation (NDRC 2006b) that the regulation duty of bioenergy development belongs to provincial government. The specific department usually the development and reform commit of each province in charge of the planning, regulation and administration of the renewable energy power projects. The plan of each renewable energy station should be involved into the general energy plan of each province. Local governments usually establish energy offices in each county to provide direct help for local villagers.

In the national level, NDRC is in charge of the planning, macro-policy making, and construction of demonstration projects like large biomass power station. Ministry of Agriculture works on household biogas digester large-medium and community level biogas projects in rural China. Ministry of Forestry works on the bioenergy plantation; the Ministry of Science & Technology is in charge of the technology development and promotion. Ministry of Finance organizes the specific fund for renewable energy development and the administrative policies of finance and taxation.

1.2.4.6 Bioenergy and rural development

Bioenergy is considered as an important method to achieve sustainable development in rural China. It is clearly described in the Renewable Energy Law that modern utilization of biomass in rural China can promote economic and social development, bring environmental benefits and enhance living standards. Government is identified as the key driver to promote household biogas and biogas projects currently due to the external benefits for the local development. It is required that government should provide necessary financial supports, organize demonstration projects, create a favorable market environment and help the commercialization of renewable energy technologies. The function of market is also be emphasized to scale up the biomass industry.

In practice, NDRC will speed up the construction of biomass power station demonstration projects in rural China and establish 50 green energy demonstration counties. Ministry of Agriculture will keep on provide financial support on household biogas digester, in the meanwhile, a specific fund will be established to help large-medium and community level biogas projects in rural China. Provincial and local governments are also required to provide financial support, stimulation policies and human resource to support the bioenergy development in rural areas.

1.3 Research Design

1.3.1 Research Aim

The aim of this research is to investigate the emerging market for biomass utilization business in rural China, to analyze opportunities and barriers of the business and market, and to summarize successful models which can be diffused and replicated.

1.3.2 Research Objectives

The research set out to achieve the following objectives:

- Identify the system boundary and key actors in the market, their needs, benefits, pursuits and concerns, existing examples of successful and failing bioenergy business in rural China. The role of government on promoting these technologies with related policy measures such as subsidies, tariffs, taxes, blending mandates etc. Other barriers and initiatives in the market, from social, economic, financial and environmental perspectives

- Summarize the possible business models and give recommendations on how to create opportunities for the market

- Provide further suggestions for government, NGOs, investors, and entrepreneurs on how to create and organize sustainable bioenergy business in rural China.

1.4 Scope

This thesis adopts a business perspective on bioenergy in rural China. The temporal scope for the research is on the short-term scale (2010-2020) so that the conclusions and recommendations are valuable for the promotion of the biomass utilization business and the development of the bioenergy industry. Considering the context of rural China, two types of biomass are explored which are agricultural residues and livestock waste. The energy potential from agriculture is expected to be 5.31 EJ in 2010 (Bhattacharya et al,

2005) and the commercial utilization of biomass for power generation is very popular currently. It can provide a high quality of Certified Emission Reductions (CERs) and can be easily financed through the Clean Development Mechanism (CDM). The enforcement of the renewable energy law provides a stable environment for the development of the whole industry.

Livestock waste is also explored because the livestock production is shifting quickly from the household level to medium and large scale livestock farms where cattle, pigs and poultry are generally raised in pens. Due to the increasing demand, around 6000 large or medium-sized farms have been established in China recently and only 20% of excrement and foul water is treated properly while only 10% of this is processed through bioenergy technology (Li et al., 2005). Manure is easy to be collected and use on site for energy purposes from these farms and the general potential of bioenergy from animal manure is expected to increase from 1.1 EJ (1997) to 2.1 EJ (2010) (Li et al., 2005). Besides, biogas digestion projects in rural China are strongly supported by the national government through the national renewable energy fund, and anaerobic technology is relatively mature. Therefore the industry is expected to develop rapidly in the coming years. Following is the figure 1-3, which shows the scope of this research.

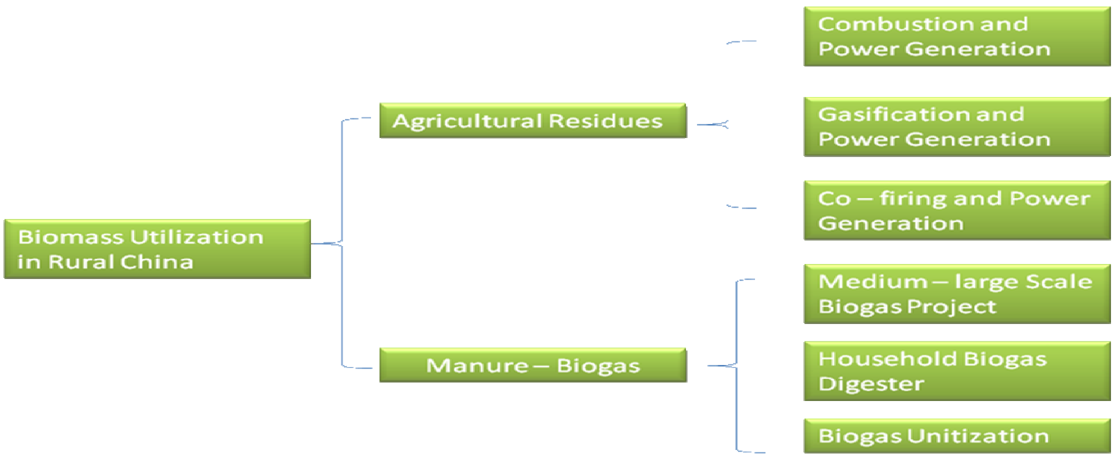

Figure 1-3 The research Scope

Biofuels and the biochemical conversion of biomass are not included in this research. First, the main bioenergy types in rural China are local resources based on the practical situation. Second, bioenergy plantations still have a highly controversial status and the non-food biofuels is still under the R&D stage and far before the commercialization. Third, current biofuels are either from four state-owned companies with the utilization of long-term storage crops or private enterprises with the utilization of swill and waste oil. Fourth, biofuels are identified as a specific industry different from biogas and biomass-based energy (Chinese Ministry of Agriculture, 2007). However, large scale bioenergy plantations should be organized in rural and remote areas of China and the success of the biofuels industry also highly relies on the business development in rural China. This research can thereby provide valuable experience for this.

Forestry residues for bioenergy are left out of the research boundary. In China, forestry production is around 900 million tons per year which is even more than straw production (around 600 million tons per year). Forestry biomass plays an important role even if not more than agricultural biomass. Besides, the utilization of forestry residues is a different system from both regulation and practice perspectives. Also, forestry residues in agricultural areas can be included into the agricultural utilization system in practice and the process is organized by individual farmers.

The geographic scope for this research is mainly agriculture areas. Northeast China is not clearly considered in this research because the agriculture system in that region is organized as a large scale agriculture farm which is not common in the rest of China. Northeast China is also out of scope because the economic, politic and also natural environments are different from other regions and deserve a specific research which cannot be including in this one.

1. 5 Limitations

Fieldwork and interviews are great challenges. It is difficult to get information in practice, to meet people who really know the situation and are still willing to tell the truth. Strong quantitative data is often not accessible in practice. Only small scale survey is employed during the fieldwork due to the lack of capacity. Operation details of the large biomass stations and biogas facilities are also inaccessible during the fieldwork because both government and private sectors consider these as no-public information. Quantitative data are mainly come from NDRC's reports and documents which are considerably as being close to the real situation.

Quantitative analysis should be employed in this research to analyze the cost-effectiveness of different bioenergy technological choice in rural China. Economic models could be used to investigate the resource supply and demand tension. The transaction cost could also be further illustrated through both qualitative and quantitative analysis.

1. 6 Audience

The audience for this work is quite broad. The potential contribution for different stakeholders from this research is intended to be:

- Policy makers, to establish or improve the policy scheme to further promote the development of biomass and bioenergy in rural China.
- Entrepreneurs, to be more clear about how to work on their businesses in rural China and where to find financial resources.
- Investors, to have a better knowledge of the emerging market and the opportunity in China's rural bioenergy market.
- Local communities, to raise the awareness of energy and sustainable development issues
- Researchers and students, to gain an original knowledge area and raise further research interests

2. Research Methods

2.1 Literature Reviews

This thesis is based on intensive and deep work of literature reviews. There were 4 types of literature reviews conducted during the research process. First, ongoing literature reviews of academic publications including important journals related to bioenergy, rural development, and sustainable business; books and other publications from major research institutes; and publications from international conference and other resources. Second, reviews of institutional literature from governments, associations and international organizations. Third, case study oriented reviews including the documents collected through the site visits and interviews. Fourth, reviews of technical issues involved in the project including data and parameters from industries and infrastructural sectors.

2.2 Case Studies

The success of this work relies heavily on case studies and the selection process of different cases is one of the most important works of the primary research. In order to explore the "real" business system of bioenergy in rural China, different cases were not based on the random principle but with clear purposes and assumptions, and were assumed to provide different results or outcomes (Ottosson, 2003; Pain & Francis, 2003; Stake, 1995 , Flyvbjerg, 2006). Trust building and deep involvement were very important in the case study process especially in those cases operated in rural areas and including local people. The process of case studies was a continuous improved process with open-end. Strong collections were built during the whole process with face to face interviews, following-up phone calls and sometimes revisiting.

2. 3 Stakeholders Interviews

According to the literature review and feasibility, stakeholders were identified as following: local people and communities in rural areas, government members from national level and local level, energy and supply chain industries, investors in major cities in Eastern China, international players, experts both in China and abroad, and NGOs (both domestic and international NGOs). Multiple sources from diverse stakeholders with cross check approaches imposed the validity and effectiveness of the information which then led to the solid results and discussions. Interview questions were designed with strong purpose but usually open-ended (See Appendix I). The emphasis included how the business works and the interaction between bioenergy projects and rural development.

2.4 Data Collections

Both primary data (e.g. interviews, site visits etc) and secondary data (academic publications, official and local documents, etc.) were applied in the thesis. The secondary data is mainly from Economic and Social Data Service of University of Manchester (Including World Bank data, OECD data, UN common data, IEA data, UNIDO data and IMF data) and the UNEP CDM data base. The secondary data were mainly from libraries of the University of Manchester, Lund University, and Chinese electronic academic publication database (CNKI), Chinese governmental websites, and publications.

3 Case Studies

Six cases are employed in this research. Cases are carefully chosen with geographic diversity and technical variation. Each case has its own focuses and can be used to describe certain typical situations in rural China. Great efforts have been made on the analysis of the business operation and the interaction with local communities.

3.1 Overview of case studies

Case 1 National Bio Energy Co., Ltd (NBE) Shanxian 25 MW Biomass Direct Combustion and Power Generation Station is the first biomass direct combustion and power generation demonstration project in China and is strongly supported by national and local governments. It is also one of the most well-operate projects (Jiang pers.comm) in China even though it is still not profitable. The problems it faces are also very typical for the similar projects. Case 2 Mishan County Medium Scale Pig Manure Biogas Generation & Community Utilization Project is a demonstration of community level biogas utilization project. It successfully involves the local community into the operation and provides with valuable experience for the scale up of medium size bioenergy facilities in rural China. Case 3 Taihua Breeding Farm Medium Scale Pig Manure Biogas Generation & Residues Utilization Project is also a demonstration project, the distinguishing features is the utilization of residues and sludge after the biogas generation process with successful involvement of local community. Case Study 4, Shenlong Medium Scale Biogas & Carbon Credit Generation Project is not a demonstration project which does not get any subsidy from the government. The project failed in the end due to the lack of financial support and the failure of the development as a CDM project. Case 5 Hangzhou Energy & Environment Engineering Co., Ltd. is the leading company in the biogas utilization market in China. They face a dilemma for further development and the Energy Service Company model is considered as a good solution. Case 6, the Global Environmental Institute (GEI) Household Biogas Digester Program provides some good experience on how to organize cooperatives to help power reduction through bioenergy development in rural areas and how to organize rural people to participate in the market economy. Table 3-1 provides with the basic information of 6 cases and figure 3-1 shows the variable locations of each case.

Table 3-1 The summary of case studies

Case	*Type*	*Operation statues*
Shanxian	Biomass direct combustion and power generation station	unprofitable
Mishan	Medium scale biogas generation and community utilization	successful
Taihua	Medium scale biogas generation and residue utilization	successful
Shenlong	Packed-medium scale biogas and carbon credit generation	failed
Hangzhou	Biogas utilization and Energy service model	unprofitable
Sichuan	Household biogas digester and poverty reduction	successful

Figure 3-1 The locations of each cases

3.2 Case Study 1, Shanxian Biomass Power Station

3.2.1 Case description

Shanxian National Bio Energy Co., Ltd (NBE) 25 MW biomass direct combustion and power generation station project is located in Hezhe, Shandong Province (see Figure 3-1.). The project is the first biomass direct combustion power station in China which is approved and supported by NDRC as the demonstration bioenergy project. The construction of the station was started in April 2005 and put into commercial operation in December 2006. The installation capacity of the project is 25 MW and the annual biomass consumption is more than 200,000 tons with the electricity generation of 160 million kWh. The main biomass resource comes from cotton straw and forestry waste. Comparing to the same scale coal-fired power plant, more than 70,000 tons of standard coal can be saved each year and therefore reduce carbon dioxide emissions by 150,000 tons (Dragon Power, 2006).

The project is invested by National Bio Energy Co., Ltd (NBE) which is a joint venture with registered capital of RMB 2 billion. Dragon Power Co., Ltd. contributes RMB 1.5 billion accounting for 75% of total registered capital, and State Grid Shenzhen Energy Development Group Co., Ltd. contributes RMB 500 million accounting for 25% of the total registered capital. Dragon Power is one of the leading private companies in the renewable energy field in China. The business of Dragon Power includes the technology transfer (mainly Ultra Super Critical steam boilers) from Burmeister & Wain Energy (BWE Denmark), design, engineering and manufacturing of biomass power plants, biomass equipment products and investments of biomass power station in China. State Grid Shenzhen Energy Development Group is one of the subsidiaries of State Grid which is the world's largest public utility enterprise and one of the major grid companies in China. NBE has obtained approval of more than 40 projects from NDRC, 12 projects with 324MW installed power generation capacity have been put into production and 7 projects are in progress with 84MW installed capacity under construction (NBE 2009). NBE alone contributes around 92% of total electricity generated from biomass currently in China (Sunsecond 2008).

3.2.2 The cooperation with the National Grid

One of the difficulties faced by biomass direct combustion project is the grid connection. First, the capacity of BDCPG project is very small (for example in this case the capacity is 25 MW) comparing to the existing coal-fired power stations in the grid which is usually more than 200 MW. The cost for grid connection is relatively high. Second, the BDCPG is not as stable as coal-fired stations due to the seasonal variance of resource. Therefore, even though grid companies should provide grid-connection service for the generation of power with renewable energy and fully purchase the electricity generated from the renewables according to the *Renewable Energy Law,* there are many delays and practical problems in practice.

However, NBE is a successful business model concerning the grid connection. A quarter of the shares of the joint venture is belongs to the National Grid. This guarantees the grid connection of all the biomass power station belongs to the NBE. Besides, building a joint venture with National Grid is also a good help for the approval of projects since this arrangement makes NBE partially belong to the state owned public utility enterprise and therefore can enjoy many political advantage on the project approval process.

On the other side, from the State Grid perspective, the drive to invest on bioenergy power station is from the following reasons: first, even though there is no clear requirement for grid companies to increase its investment on renewables according the renewable energy law, it is well recognized that this will be the main issue in the next decades. The National Grid would like to take one step forward to be the premier mover. Second, the success of biomass power station is highly depends on the stability and costs of the resources, and one station unusually will covers more than one hundred kilometres radius of the area. Therefore, being the premier mover means the possibility of controlling the biomass resource in one area. Third, local experience like resource collection, supply chain organization and the adaptation of equipment in local environment are greatly valuable in this future. Last but not least, the draft proposal of 4% compulsory renewable energy quota for grid has already been submitted to NDRC (CB.cn 2009), if passed, all grid companies and power generation groups will be enforced to work on this goal. It is a good way to go over the gap of grid connection between the renewable energy power stations and the grid companies if the joint venture can be organized the

In the Shanxian project, 20% of the investment for the project comes from NBE while the rest of 80% is from banks and this is also the case in all other 6 ongoing projects of NBE. The support from financial sector is crucial for the company. Besides the joint venture with National Grid, Dragon Power which owns 75% of the share of NBE also gets a 150 million dollars risk investment from CITI Bank. This is a great help for the operation of NBE and its 6 projects especially under the financial crisis situation. However, the IPO of Dragon Power has been delayed due to the operation loss and the crisis.

3.2.3 The initial investment, operation cost and the on-grid electricity price

In general, the initial investment for biomass power station is 8000-10000 Yuan per kW capacity well the coal-fired station which is only 500-600 Yuan per kW (Kai 2009 pers.comm).The budget of the Shanxian project was expected to be 25.6 million Yuan in the original plan but the total investment is 37.7 million Yuan which is around 50% more than the plan (NDRC 2008). The main reason for the excess of the budge on initial investment is due to the technical problems, the characters of biomass resources in China is significantly from Denmark where the technology of BWE is working smoothly. The moisture content is pretty high is China which leads to the coke on the inner side of the boiler. Besides, the Chlorine concentration is much higher in the straw and this leads to the corrosion of the pipeline and the high moisture adds up this process of corrosion. Both of the problems increase significantly the initial investment and the operation costs.

The cost of the electricity generated from the station is more than doubled comparing to the average price of coal-fire stations in the regional grid. As listed below, the cost per kWh is 0.84 Yuan if the whole operation time can more than 6000 hours per year and the resource price or straw is around 250 Yuan/ton.

Table 3-2 The cost of power generated in Shanxian Project

Operation Time (hours/year)	Cost (￥/ kWh)
5000	0.92
5500	0.88
6000	0.84

Source: NDRC 2008

The price of on-grid electricity from coal-fire station is 0.346 ￥/ kWh. According to the NDRC's regulation of 0.25 ￥/ kWh renewable energy subsidy, the price should be 0.596 ￥/ kWh. However, since Shanxian Project is the national demonstration project, 0.2 ￥/ kWh of temporal subsidy has been provided by provincial government according to the Renewable Energy Law and the current price is 0.796 ￥/ kWh (NDRC 2008). Even though the price is still below the cost of the electricity generated from the project, working properly with this subsidy is still the best way if considering the huge initial investment and the operation and maintenance cost.

3.2.4 The supply chain

Two factors make the supply chain as the bottle neck of this project. First, the cost for biomass collection consists of around 50% of the total cost of electricity generation. The average biomass price for biomass collection (before transporting and processing) is around 250 Yuan/ton (NDRC 2008). The generation of one kWh of electricity requires at least 0.6 kg of Straw (Peng 2008). It then can be calculated that the cost of straw resource is more than 0.15 Yuan/ kWh which is almost half of the total cost the production of electricity. Second, the operation of this power station requires 0.20-0.22 million tons of biomass per year. Each household can provide at most 50000 tons of straw per year which are separated in two harvest seasons. For households, there is almost no losing if they do not sell the straw and this requires a high transaction cost if the power station collect the resource directly from households and rapid increase of raw materials from 100 Yuan in the beginning of 2008 to be more than doubled in less than one year (Xu pers.comm).

To maintain the stability of the resource supply, the Shanxian power station established a collection network with eight resource collection stations in the area around more than 100 km away from the power station. Each of the station has a storage capacity of 8000~ 13000 tons. The stations purchase the resources from professional brokers who are mostly local people. The exit of the brokers makes the collection process much easier comparing to the conventional way in which the station has to face individual households and bargain the price separately. However, those collection stations are still in the disadvantage positions especially when the brokers form a price union or become a monopoly in the regional area. Due to the high initial investment and the transportation costs, the power station has to search biomass resource within the limited area and therefore is always lack of the capacity to bargain the price in the market. The following figure shows the collection chain of the project.

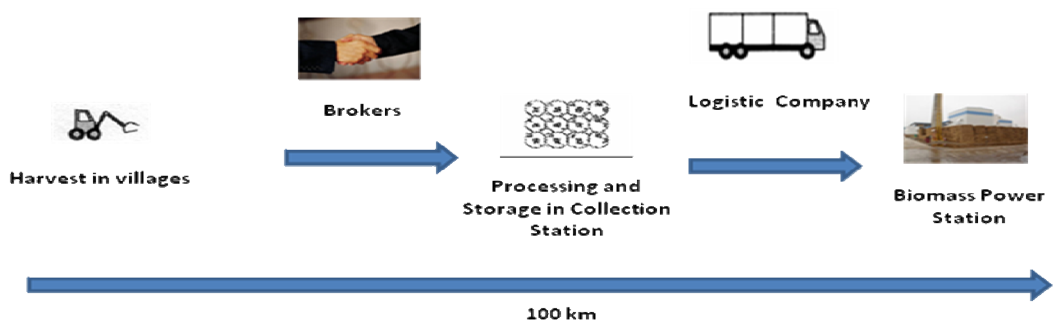

Figure 3-2 The supply chain, harvesting, transporting and processing of Shanxian Project

The emergence of brokers has significantly reduced the difficulty of resource collection because the power stations do not need to face individuals in villages which is very human-intensive and inefficient. However, this also increases the cost of the resources. The following figures show the cost of resources in different stage of the collection chain. In average, brokers get a benefit of around 50 Yuan/ton. This is around 15% of the total cost of the resource.

Table 3-3 The cost of resources in different stages of the collection chain in Shanxian project

Name of resource	Price in which brokers collected from villages (Yuan/ton)	Price in the collection station (Yuan/ton)	Cost in the power station (Yuan/ton)
Wood scraps	220	260	390
Cotton stalk	140	180	360
Sawdust	180	220	330
Branches	180	240	370
Bark	160	200	350
Corncob	160	220	330
Peanut shell	200	260	350
Average	177	225	354

Resource: data from NDRC Investigation and Research Report 2008

Another 125 Yuan is needed before the resource arrive from the collection station to the boiler. According to the survey, the transport cost is around 25 Yuan/ ton, the processing cost of raw materials in each station is around 40 Yuan per ton and the staff salaries is 20 Yuan/ton. The rest 45 Yuan is mainly due to the losses during the transportation and processing of raw materials. 25% of the raw materials are lost in the whole process while about 8% are lost in the processing stage. This is count for about 12% of the total costs of the recourse. Following is the composition of the overall costs.

It is the optimistic estimation in the feasibility research level of the project that makes the current situation very hard. It was estimated that 30%-50% of the biomass generated from agriculture production process could be collected for the power station, but the really situation according to the survey is around 15%. This leads to the largely expansion of the collection zoon from a 30 km area in the plan to a more than 100 km area. The increase of the collection chain requires more input on the transportation, more working staff on the logistic process and a higher rate of material loss. Figure 3-3 shows the costs of different stages in the collection chain.

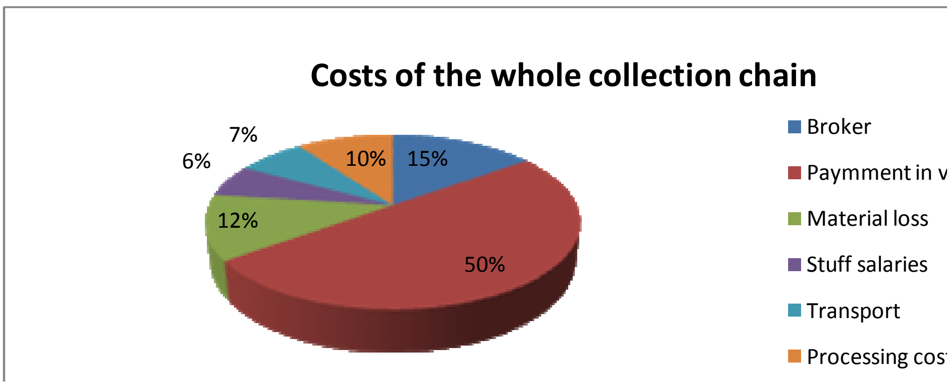

Figure 3-3 The supply chain cost in sectors in Shanxian Biomass Power Station

Data resource: NDRC 2008

3.2.5 The economic and social benefits

As discussed above, the payment of around 250 Yuan/ton goes directly to local people before raw materials come into the collection station. The consumption of the raw materials is around 0.2 million tons a year. Therefore the income of the local people is expected to increase 50 million Yuan. More than 75% of this amount of money goes directly to local farmers who work on ground in the form of cash flow which is even better than the governmental subsidy for farmers which are usually in the form of loan, fertilizer or other stuff for production. The other 25% goes to brokers who are mostly also from local villages. This provides around 1000 job opportunities in the whole collection chain. Also, the project brings a significant environmental benefit by saving approximately 50,000 tons of standard coal. Even though the project is not profitable, the operation of the project produces a big externality in the local level.

3.2.6 Conclusion

In summary, over estimation of the possible amount of resources is the major drawback of the project. In the planning stage, it is necessary to calculate the total amount of resources and also the possibility of accessing the resources which is even more important. It is normally considered that 50% of the biomass resources can be collected for the power generation. But only 15% - 20% can be collected in practice. This big gap leads to the increase of collect radium from 30 km to more than 100km around the power station and significantly increases the operation costs. Also, how to make business with millions of local villagers who are lack of business sense is another challenge. The existing of brokers is not the best solution because it also clearly increases the costs and cannot maintain the stability of the resource supply. National subsidy is crucial for the operation of the project currently. However, it cannot guarantee the profit of the project. The business model of this project is good enough to maintain the operation of the project even if it is in deficit. The National Grid with a strong willing to become the primary mover in this new market is big enough to support the loss since the main purpose of the demonstration project is not for making benefits but to accumulate experience for further development of the biomass power generation market. Also, the support from the investment bank is also a good help.

3.3 Case Study 2, Mishan Biogas Project

3.3.1 Case description

Case study 2 is the Mishan County medium scale pig manure biogas generation and community utilization project which is located in Jincheng, Shanxi Province. According to the national bioenergy strategy for 2005-2020, Chinese government began to change the focus of national subsidy on the utilization of biomass in rural areas in 2008, switching from household level biogas digesters to community level biogas facilities which are usually media or large size animal manure treatment facility or straw anaerobic treatment facility or combination of both. Only less than 10 projects were chose in 2008 as demonstration projects to get the subsidy from the national government, and most of which are still under construction. Mishan Project is the first few which have already been used. The project is located in Mishan village, Jincheng, Shanxi Province (Fig 3-1). At the end of year 2008, more than 300 households in Mishan County, Shanxi Province started purchase biogas from a local media-large size animal manure anaerobic treatment facility for cooking, shower and heating purpose. Pool volume of the facility is 500 cubic meters which is suitable for the treatment of more than 1200 pigs' waste manure as well as agriculture residues like straw from the same region. The biogas generated from the facility is transported through pipelines to local villagers for cooking, shower and heating.

3.3.2 The subsidy and price advantage

Subsidy makes the great contribution for the initial investment of the project. In Mishan County Project, the investment for the whole project is around 3.5 million RMB. National government provides 1.2 million RMB as a subsidy and local government also spent 1 million as a match of the national support. The pig farm takes only a small portion of duty on the initial investment of the project but is charge of the maintenance and operation of the project. Each household also needs to pay 1500 Yuan RMB which is mainly used for the change of stove and the installation of pipeline into each house.

Shanxi Province is rich in coal resource and coal is commonly used for heating and cooking before. Rich households in Mishan also use liquefied petroleum gas (LPG). The average bill on energy for each household was around 100 Yuan RMB per month before. After the utilization of biogas, the average consumption for energy is 24 Yuan per month for households who share straw with the facility and 45 Yuan per month for households that do not have straw or do not want to give to the facility for free. It is obviously that biogas is much cheaper than coal or LPG. With a relatively good quality of energy service and cheaper price, the biogas is accepted among local villagers in a short time period. Besides, considering one household with a land of 12000 square meters, the cost of annual chemical fertilizer is around 15000 Yuan. This amount of money can be saved if they choose to use the organic fertilizer from the project. In fact, the organic fertilizer is much more efficient than chemical fertilizer and can achieve a 30% increase of output (CNLG, 2008).

Table 3-4 The economic comparison of utilization of biogas and Coal & LPG in Mishan Case

	Stove	***Cost***	*Fertilizer*	*Production*
Biogas	Free	24 Y/ m for partnership 45 Y/ m for no partnership	Free organic fertilizer	Increase 30%production Sale with higher price
Coal & LPG	Not Free	100 Y/m	Purchase chemical fertilizer	Cause environmental problems

3.3.3 Public partnership with customers

The price of the biogas is used to maintain the stability of the biomass resource. In Mishan village, each household is encouraged to provide 800 kg straw to the biogas company for free. As a return, the household can purchase the biogas with a discounted price of 0.8 Yuan RMB per cubic meter. Comparably, the household without the straw submission, has to pay for 1.5 Yuan RMB per cubic meter. Also, those villagers who provide straw to the project can collect biogas sludge freely which is the high quality organic fertilizer and can help save the use of chemical fertilizer.

According to the calculation based on local situation, 1 kg of maize straw can generate 1.5 cubic meter biogas, and 800 cubic meters of straw is equal to 1200 cubic meters of biogas. The average combustion of local people is around 1.5 to 2 cubic meters of biogas per day and around 750 to 800 cubic meters per year. In this case, the resource supply is enough to support the whole year even if without enough farming waste. This guarantees the stability of the biogas supply.

Even though the project is subsided by the government, local villagers still should pay 1500 Yuan to install pipelines inside the house and change their stoves. This payment involves in their personal interests into the biogas projects and makes they really take care of the facility. Besides, once they change their traditional system for cooking and heating into new stoves, it will last for a long period. This also maintains the long-term operation of the project. Also, since local customers decide to use biogas as their main energy resources, they would like to search for cheaper price by providing 800 kg of straw per year to the project. The biomass itself costs almost nothing in the local village. This arrangement successfully goes through the resource problem of the facility.

3.3.4 The energy service office

A local energy service company has been organized by the project owner, village committee and biogas service centre of Jincheng. The company set up a local office in the village to collect fees and provide another service like consulting, monitor, sell stoves and facility maintenance. People work in the office are from the local village as well which is a big advantage because they have a good knowledge of their customers and most probably even personal know them. This is very helpful for the operation of the system because these staff have a direct interest in providing service and the collection of fees

One or two local staff from the office is trained to be technicians in the village. They are required to visit each household once a quarter to monitor the facility and the system and also in charge of unexpected technical problems. This is a cost-effective way because first, it provides job opportunities for local villagers which makes the project much more popular, second, all customers know the person who works as a technician and can always find him/her easily not always in the working hours, third, technician lives in the village which is a clear advantage especially if the project is in remote area with bad road conditions, fourth, the payment is much cheaper than hiring a technician from outside and has to spend money on transport to the village. Maintenance is a significant success of this energy service office model.

3.3.5 The smart payment system

Farmers use pre-paid system to purchase biogas. Each household has one intelligent IC card to activate the main gas valve and farmers have to go to the local office to charge the IC card before using the biogas. This payment system is much more efficient than the conventional system in which technicians of the company have to go every month to visit the customers and collect the fee. Those technicians are also local people and this usually make the fee collection very hard because there is a culture in rural China that it is a shame to ask for money from people who he/she familiar with, especially ask for a small amount of money (in this case, around 40 RMB). Farmers are much more convenient with the new system because fist of all, they do not have the feeling to be asked for money, second, they feel like they are using the high-tech system and have the same life style as people live in cities, third, people in rural China are always like to compare with each other, so if using IC card for prepayment is considered in mainstream as a good thing (for example in this case), all households in the village would like to use it.

3.3.6 Conclusion

The energy service company can be scaled up as a larger energy service company in the whole region. But the key issue is that the company should have a decentralized local office in each village to conciliate close relation with customers and deal with the complicated issues like the fee and resource collection work. Local workers is a key issue to the large scale energy service company because the trust building is the most important factor here and can hardly be done by people from outside. Besides, it is much better if the company can involve the village committee, which is also a good way of trust-building.

The main problem for replication is the initial investment. In this case, as a demonstration project, the investment is covered by the national subsidy which is far less enough to support the replication. However, this project provides a successful model to link the commercial and financial interests of investors and farming industries within one organization. This is also highly supported by the government even if not all projects can get subsidy. Local villagers also like to be involved in the project because of the benefits. So it is a good direction to discuss the possible commercial investments from outside investors based on this model.

It is proved from this project that community level biogas project is a good way to provide local people with sufficient biogas for cooking, shower and warming. The initial investment relies on subsidy which would otherwise goes to the household level biogas digesters. This centralized subsidies linked interests of different actors together (such as government, villagers, enterprisers of the farm industry) into one organization and can also provide more job opportunities for young people in the villages.

The localization of staff is the key factor to build trust with villagers and maintain the stability of the resource supply and operation. Besides, a good business model is necessary for the commercialization of biogas and the facility maintenance. Price is an efficient incentive to ensure the stability of the resource supply. When coming to replication, the energy service company should be also in charge of the investment or at least, should search for investments actively.

3.4 Case Study 3, Taihua Biogas Project

3.4.1 Case description

Taihua breeding farm medium scale pig manure biogas generation & residues utilization project is located in Pingxiang, Jiangxi Province. The farm belongs to Livestock Technology Co., Ltd. The farm has a capacity of 4500 pigs per year in 2007. The biogas facility was built in 2006 with the financial support from both national and local government as a demonstration project. The facility itself went well for the waste treatment. But it also caused a few problems: first, biogas could not be fully used on site and emitted directly to the atmosphere; second, liquid sludge went directly to farmland and led to the eutrophication of land; third, there was no facility to treat solid sludge which then led to the around environment; fourth, the sludge increased the risk of pig diseases. How to treat biogas and sludge and utilize them properly is becoming a very urgent problem of the breeding farm biogas project in rural China (Qin pers. Comm.).

3.4.2 Biogas utilization

To deal with these problems, both national and local government provide further investment of around 0.6 million RMB to support this demonstration project. The first issue is the utilization of biogas. The project has been innovated in the following ways: first, the volume has been extended to 1200 m^3; second, biogas is connected into around 100 households through PVC pipes in a distance of 1.5 km; third, one 200 m^3 biogas storage tank has be built to maintain the stability of the biogas supply. Villagers got biogas equipments from government for free, which made the popularization of biogas in a short period.

Fugire 3-4 The biogas utilization facilities

The biogas is provided freely for the villagers currently. Actually there is a charge scheme already for the villagers which is around 0.6 Yuna per/m3 (Peng. Pers.comm). However, the final decision is to provide biogas for free in the trial period which may be two years long. First, villagers are lack of the willing to use biogas if they need to pay for that. Even it is cheaper than coal, villagers still would not buy it if they have no personal experience about this. So the first two years is considered as a period of education. Second, operation cost of the facility can be subsidized by the profit from breeding. The environmental benefit instead of the energy purpose is the main purpose for the breeding farm to build the facility which otherwise would be fined for the pollution. It costs extra money to install meters which will lead to the rebuild of pipes. The pipe line system is expected to be renewed in 2 years and the meter system can be installed during the same time with much lower cost.

3.4.3 Residues Utilization

A three stage liquid sludge aerobic treatment facility is established in the farm. The system consists of three sediment ponds and aerobic channels connected the ponds which are distributed in a piece of farm land of 200 acres. After the three sediments ponds and the aerobic channel, the quality of the liquor is good enough for direct irrigation. Villagers can also freely open the channel to get sludge for fertilization purpose if they think more nutrition is needed.

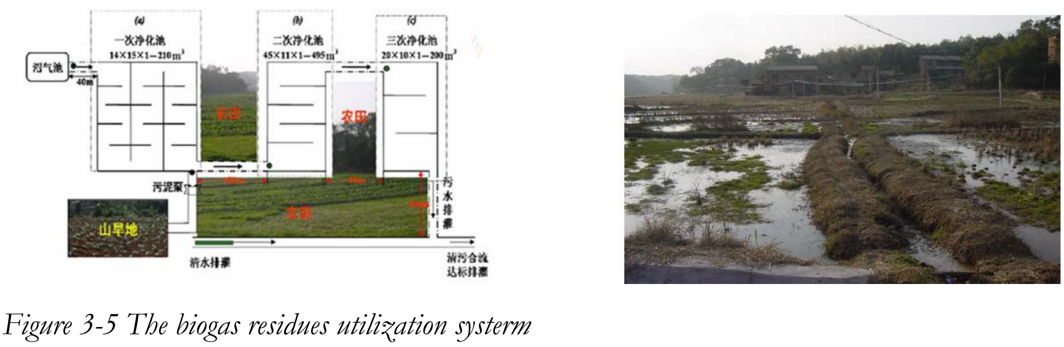

Figure 3-5 The biogas residues utilization systerm

In order to utilize the liquors, a cooperation association is established between the breeding farm and villagers around. They organize a "pig-sludge-agriculture" model. Sludge after the three stage treatment should be used as organic fertilizer directly back to land. In practice, the agriculture part can be rice, vegetables, sweet potato or even fish ponds. There are many benefits generated from the system, the breeding farms achieve zero emission target as a demonstration project, sludge is used efficiently, the production of the agriculture land is increased, villagers do not need to buy extra chemical fertilizers. Theoretically, villagers should pay for the organic fertilizer, and the breeding farm also need to pay for the use of villager's farm land. Since both parts (breeding farm and villagers) benefit from the association, they decide not to pay between each other.

3.5 Case Study 4, Shenlong Biogas Project

3.5.1 Case description

Shenlong medium scale biogas & carbon credit generation project is in Gaoan County, Jiangxi Province. Four local breeding farm owners come together to set up this Shenlong Cooperatives to scale up their business and to reduce risk. Due to the strict environmental standards, they decide to build a modern biogas digester facility for each farm. The plan is to use biogas generator for the on-site use of electricity like heating and mixing of fodder. This will help them reduce the consumption of electricity from the grid. Since they do not want supply biogas to local communities around, it is hard for them to get subsidy for the project. They then decided to apply for CDM project since four farms together can actually generate a big amount of carbon credit. World Bank would like to provide 30% loans for this project if the local government can vouch for the return. However, the local government does not accept the proposal to be guarantor for this project. This finally failed the biogas project.

3.5.2 Why and how to get help from

In this case, the project owners do not want to provide the biogas to local people around. First, it will be very complicated if they charge local people for the biogas. They all know each other and it is not easy to ask for money from culture perspective. Also, they have to install the pipe system to each household and take the maintenance responsibility which is a big extra cost for local livestock enterprisers. Besides, comparing to supply biogas to the community freely, they can easily buy a small biogas generator which is usually less than 8000 Yuan to provide electricity for on-site use. This can really bring back some economic benefits for the project owners and the electricity from biogas actually is always not enough for the operation.

Local government does not want to provide subsidy or other form of help mainly because that the project cannot provide extra benefits for local community. In this case, the main purpose is to meet the environmental standards of the livestock farm which is the required responsibility of the project owners. Instead of providing biogas for local community, the project is planned to use biogas for on-site use, which will not provide further environmental nor social benefits for the sustainable development of local people. Local government does not have experience on CDM nor World Bank project and it is hard for them to take the risk especially when the project is not a demonstration project.

3.5.3 Carbon credit and CDM project development

The digester is designed to be 180 cubic meters. The total cost is listed below. The total cost for one facility is expected to be 90000 Yuan. .

Table 3-5 The initial cost of a medium size biogas project

	Cost	Amount	Total
Biogas Generator	7500 Yuan	2	15000
Construction cost	130 Yuan/m^3	180	23400
Material cost	280 Yuan/m^3	180	50400

Since this project will not supply biogas for local households around these farms, it is hard to get the subsidy for the initial investment. The owners decide that they can combine these four facilities together to apply for a CDM project. The greenhouse gas reduction credit for each facility is too small for a CDM project due to the high transaction fees. But when four facilities are combined together, it can generate enough carbon credit. The profit from the CDM credit is expected to be 30% of the total investment according to the consultant company they hired for this project. Therefore, they planned to invest on this project even without subsidy.

World Bank would like to provide a loan of around 30% for the initial investment and agree to help develop the new CDM methodology of this combination project. The plan was to pack up more projects together to organize a Programmatic CDM project (PCDM). World Bank also agreed to purchase all the carbon credit generated from this project. The only pre-condition is that local government vouch for of the safety of the loans and help organize these medium scale biogas facilities together. However, the local government does not accept the proposal to be the guarantor for this project. They also lack the capacity to organize these projects together.

3.6 Case Study 5, Hangzhou Energy Service Model

3.6.1 Case description

Hangzhou Energy & Environment Engineering Co., Ltd. (HEEE) is a leading high-tech enterprise in Zhejiang, China, specializing in designing, constructing and general contracting large-scale biogas projects, as well as developing and manufacturing complete equipments of large-scale biogas projects. The company is established by Prof. CAI, Changda who was a professor of Zhejiang University and had an experience of over 30 years in the biogas technology and has undertaken many national scientific and technological key tasks, national 863 project and scientific supporting projects. The company owns a series of independent and mature technologies which make it in a very good position in China's bioenergy market.

3.6.2 Quality dilemma

One of their advanced technologies of HEEE is on-gird biogas electricity generation system. All three demonstration projects in China are built by this company. However, as a leading player in the market the company faces a problem for further development. Because of the leading technology and high quality of the construction, the total cost of the project is higher than other competitors in the market. For farm owners, they do not want to pay for extra money for higher quality of the digester if they cannot get subsidy from government. Besides, as the owners of farms, the main purpose of building the digester is to achieve environmental targets. Once the manure and waste water can be treated properly to meet the national standards, they would not pay for extra money for the energy facilities.

Table 3-6 All on-gird biogas electricity generation station in China are built by HEEE

Project Name	Installed power	Substrate
Mongolia Mengniu Aoya Milch Farm Biogas Plant	1 MW	500T/d manure & 500T/d wastewater
Beijing Deqingyuan Eco-farm Biogas Plant	2 MW	212t/d
Shandong Minghe Poultry Biogas Plant	3 MW	Milch cow manure280t/d

Resource: HEEE 2009 (http://www.hzeeec.com/english/gcy j.asp)

3.6. 3 Energy Service Company Transaction

Energy Service Company (SECO) is discussed in the committee of the company as a possible solution (Qing pers.comm). Instead of the implementation of the biogas project construction contract, the company can play in a different role as to invest directly on the biogas digester system together with livestock farms, to provide service of manure and waste water treatment for farms and to organize the electricity generation business by itself.

Key barrier is the high initial investment. Loans from banks are considered as a solution. The other way is to get financial support from investment bank. HEEE has already get some contacts with venture capitals and big investment firms (Wang pers.comm). However, they have not made the decision because as a private company, he does not want to dilute his control of the company. Besides, national policy and subsidy is another issue. The project cannot be profitable under the current subsidy level. But certain temporary subsidy or other support can be provided according to the renewable energy law (Qin pers.comm).

3.6.4 Current development

HEEE has recently signed a contract with Shanghai Milk Group to establish a 3 MW biogas plant for three new cow farms which are close to each other in Haifeng Country Jiangsu Province. The new project uses is planned to use SECO model to provide service for waste treatment of 30000 milk cows. The service is free but HEEE has the ownership of all the benefits from biogas and sludge which can be manufactured to high quality organic fertilizer. The initial investment is partly from the company itself, provincial government and loans from the bank. However, the project is most probably will be nonprintable (Qin pers.comm) based on the current subsidy level. In Jiangsu province, the manure treatment fee is 0.9 Yuan per ton if collected by the civil waste water treatment facility. But in this case, the energy service company provides the free service for the waste treatment. The service fee can be a big portion of the income if the consensus can be achieved by the energy service company and the farms. This requires more work from the government to tight up the waste treatment standard and to help build the service mechanism. Besides, residues for organic fertilizers are also considered as a possible income if being used properly as the organic fertilizer. However, this requires the establishment of the market channel.

3.7 Case Study 6, Sichuan Household Biogas Digester Program

3.7.1 Background

Global Environmental Institute (GEI) is a Chinese non-profit, non-governmental organization established in Beijing, China in 2004. The purpose of GEI is to search for market-based models for community development to addresses environmental degradation, deforestation, climate change, and poverty holistically, to help farmers establish skills and technical capacity needed to benefit from the market economy. In China, household level biogas digester has been subsidized by government for more than 30 years. However, this subsidy is proved to be not effective (Qin Pers.comm) and delays the commercialization of the biogas digester system. Since 2004, the GEI Rural Team has implemented an innovative biogas-organic agriculture project, which serves as a model for sustainable development in western China. One of these programs is organized in Baoxing County, Sichuan Province. The program is funded by some international NGOs and around 100 households are included in this program.

3.7.2 Case description

The cost of one biogas digester is calculated as 2400 Yuan in Baoxing County with labour cost exclusive. The subsidy from national government is 1200 Yuan per household and this money goes to the local energy station which is a subsidiary body of the local government. GEI makes the agreement with the energy station to provide the other half of money to help households of the program. This money is mainly used for procurement of the construction materials and the digester and the payment for technicians. Household villagers would get cash from neither the energy station nor GEI.

GEI also participates in the innovation of the digester. It works together with local facility producers to continuously improve the quality of the digester based on the feedback of local users. They also develop standardized products and help the producers to commercialize its products.

3.7.3 Cooperative association

In the program village, GEI help local farmers to form rural cooperative association. The main purpose is to organize villagers to help each other for the construction of the digester. It is well recognized by the program officers and the local energy station that the digester should not give to local villagers freely so that they will pay more attention to take care of it. Besides, the association can invite technicians to provide training service and monitoring of the operation. Also, one or two members will be chose to learn from technicians about the basic and daily maintenance knowledge that will then be in charge of the daily operation of the facilities.

The association also has other functions. GEI provides with the association a certain amount of money which is usually around 20000 Yuan as a fund for micro-finance loans. The money is for association members only with the purpose to help their agriculture production. The association is chose to organize the fund because, first, members inside the association have a strong belief with each other; second, members can mutually supervise each other to make sure the return of loans; third, it can help avoid many political risks since micro-finance project is still very sensitive especially if the money comes from international NGOs. Members can borrow the money only as a group of 4 or 5 households. They all take the responsibility to pay back the money together so if one household fails to return his portion, the rest households have to return for him instead. This is a strong drive for all households to return the money.

The sludge from biogas digester is used as organic fertilizer. GEI help the association for marketing so that their organic productions can sale in a high price. The association is used to insure that no chemical fertilizer is used during the whole process among all members. They all know that if they broke the rule then it will harm the benefits of all members. This is a strong drive for all members to maintain the role and is much more efficient than the normal contract (Wang pers.comm).

4. Discussion and Analysis

4.1 Problems and Solutions of Biomass Power Stations

As the first large biomass direct combustion power station in China, Shanxian project faces a lot of problems which are also typical among many biomass power stations. This provides a good learning experience. First, the biomass resource in rural China is a mixture of many different kinds of resource from both agricultural and forestry residues. This is very different comparing to many other countries where only the single resource is used. The mixture resource has lower energy density and higher inorganic constituent concentration. So the BWE boiler which has already been well operated in many projects in developed countries faces a much higher operation and maintenance cost in China.

Second, for the energy efficiency purpose, single-boiler technology is used in most of the current projects. The capacity of single combustion facility is usually more than 20 MW (25 MW in most of the NBE projects) and requires a high initial investment which is more than 0.2 billion Yuan. Besides, this type of large scale project requires a more than 0.2 million tons of biomass per year. Considering the situation that the biomass resource is distributed into large amount of individual households scattered in small villages. The requirement of large amount of biomass resource leads to a sharply increase of costs on collection, processing, storage and transportation process (Qin, pers. Comm.). Demonstration projects can bear the high cost with the national subsidy. But this high cost makes a big barrier for further development of the whole industry.

Finally, from the investment perspective, most of the ongoing projects are invested by national-owned energy companies or banks only. The City Bank is the only commercial investor in this field which invest 0.15 billion dollars on Dragon Power. However, the IPO have been delayed due to the operation situation and the current final crisis. This brings a high risk for investors. Neither private investors nor local companies would like to go into this field (Jin, pers. comm.).

Comparably, small scale biomass power station (5-10 kW) has many advantages (NDRC, 2008). First, all related technologies both gasification and direct combustion are domestically available and this can help highly reduce the initial investment. Besides, the initial investment is less than 15 million (Economics Daily, 2006). Both domestic investors and local government have the capacity to invest on this kind of project. Third, the biomass demand is around 50000-100000 tons per year and the collect radius can be easily controlled (NDRC, 2008). The small scale project also has flexibility on the amount of biomass resource and can be broadly used in rural China (Economics Daily, 2006).

In practice, primary movers in the market have already realized this. For example, NBE and Dragon Power have recently changed their plan for new projects, decreasing the capacity from 25 MW to 1.2 MW (Jiang, pers.comm, NDRC, 2008). However, it does not mean large scale biomass power station cannot work well in China. In some large farming areas like Northeast China (Jilin, Liaoning, Heilongjiang Provinces) and Xinjiang Province, the agriculture is organized by large state-owned farms and provide with the stale biomass supply. Therefore, the large scale biomass power station has much more potential in these areas (Qin pers.comm).

However, small scale projects also face some problems. First, as discussed in the Shanxian project, grid companies do not always want to invest on the grid connection to small scale power station and renewable power stations. Small scale biomass projects are much smaller than coal fire stations and are not very stable which causes a big problem for the safety of the grid. Besides, the resource competition between small scale power station and paper industry can be very intensive in some areas especially without proper plan and management from governments (Sun et al. 2008).

Co-firing of biomass is another possible choice. With low cost equipment upgrading, biomass can be added into the coal fuel supply of the existing coal fire power station (Ralph 2003). Since biomass ratio can be variable among a broad range in the co-firing station, it has a low elasticity on demand of biomass resource and has a stronger capacity to control the price. However, co-firing is not included into the renewable energy law and cannot get the renewable energy subsidy. Currently, only Shanghai Xiejin Co.ltd has 21 small thermal power stations in East China which add small portion of biomass for co-firing.

4.2 Commercialization of Biogas Power Stations and Energy Service Company Models

Many efforts have been made on the anaerobic manure treatment and biogas utilization in rural China. More than 10 thousands of farms have been built in the past five years (NDRC 2008) and it will still be strongly promoted by the government because it can help bring more income for local people and help maintain the price stability of the livestock supply (Lin pers.comm). However, less than 30% of these farms installed the waste treatment facilities even though it is required by the government. This leads to the heavy pollution in rural China and also causes other social problems. On the other hand, if being organized properly, livestock manure treatment can actually be a good solution of waste-to-energy (Ralph 2003) and it also has a great potential in China (Wang 2008).

There are three main technical tracks of utilization of the biogas generated from the anaerobic treatment facilities. In Mishan and Pingxiang case, biomass is provided for domestic utilization like cooking and heating. Usually, local people are not charged for this (Pingxiang Case) or are charged for a small portion of the cost (Mishan Case). Since this track brings external social and economic benefits to local community, it can be financed by the government as demonstration projects. However, due to the high initial cost, the governmental funds can support no more than 20 projects each year (Wang 2008) which is far behind the development of the whole livestock industry in rural China.

In Shenlong case, the project owners choose to use the biogas for on-site electricity generation. In this case, governmental funds can hardly be used to support this type of projects. Usually they have to search for other external investors because the initial investment is too high for farm owners themselves. CDM money is a possible source for the support of this kind of projects. But as discussed in the case study, farm owners and the local governments are still lack of the capacity to run a CDM project.

The HEEE has built up all the three larger scale on-grid biogas to electricity projects. Electricity generated from biogas is included in the renewable energy subsidy scheme and the income from the electricity export is a good help for the commercial operation of the project (Wang 2008). However, the initial investment is still high and is mainly from the government currently. Due to the scarcity of the national funds, the government cannot support the best technology and this leads to HEEE's dilemma as discussed in the case study.

To deal with this problem, HEEE and also some other biogas construction and manufacture companies in China are attempting to introduce the Energy Service Company (ESC) model in the biogas utilization market. As described in the case study, the energy service company invests or partly invests on the anaerobic facility and provides service for the waste water and manure treatment for the livestock farms. As a return, the company shares the profits from electricity generation. The finical support of these three tracks are summarised.

Table 4-1 Summary of the financial situation of biogas power stations in China

Utilization Types	*Financial resource*	*Problems*
Domestic Utilization	Mainly subsidized by the government	Governmental funds can support only a small portion of projects each year due to the high initial cost.
On-site Electricity Generation	No governmental funds, searching for investment by the farm owners themselves	Hard to find investments due to the high financial risk
On-grid Electricity Generation	Included in the renewable energy subsidy scheme. But the initial investment is still from the government	Best technologies cannot be promoted due to the scarcity of the national subsidy

For the energy service company, currently three main types of profits (Qin, Cai, Wang pers.comm): electricity generated from biogas as renewable energy, carbon dioxide reduction credits (CERs) and solid organic fertilizers (SOF). On-grid electricity generated from biogas project is included into the renewable energy subsidy scheme which can get a financial support of 0.25 Yuan per kWh. Besides, like HEEE's new project in Jiangsu Province, the national government and provincial government will also provide an extra temporary subsidy as a compensation for the primary mover (Qin pers.comm).

CERs are based on the Clean Development Mechanism (CDM) of Kyoto Protocol. Electricity generated from biomass replaces the use of fossil fuel in the grid and reduce the CO_2 emission. The credit can be sold in the international carbon market as a CDM project. The price for solid organic fertilizer is variable from 500 to 1600 Yuan per ton and the price is expected to be much higher in the near future due to the increasing concern on organic food and environmental protection (Wang 2008). The following figure is the calculation by Wang (2008) based on a typical project which has eight 2500 cubic meter anaerobic digesters and two 1260 kW generators with a total initial investment of 51.3 million Yuan. The daily biogas generation is expected to be 20000 cubic meter, annual electricity generation 14.6 million kWh, solid organic fertilizer 5000 tons and the annual CERs 80000 tons.

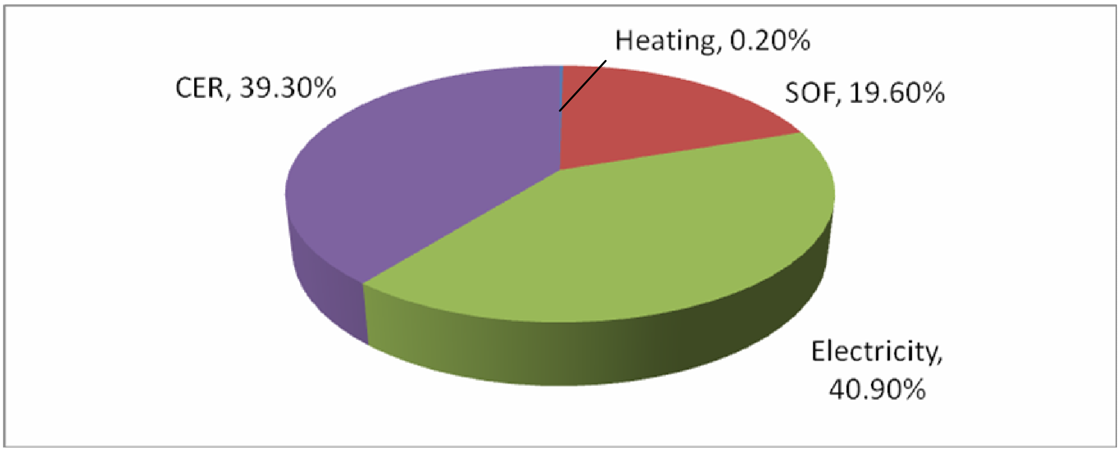

Figure 4-1 The profits generated from a typical biogas power project.

Source: Wang 2008

However, there are also uncertainties here. First, as discussed above, grid collection is a big challenge in practice and usually the initial cost of the grid connection has to be shared between the energy service company and the grid. Also, the connection can be delayed due to technical, social and practical problems. If the grid connection is delayed which is very possible, the biogas has to be burnt directly and this leads to the high operation costs in the early stage of the project. Second, the carbon income is highly risk (Johansson, Qin pers comm.). According to the May 2007 pipeline of CDM projects (until 31st May, 2007), only 3.59% out of a 178 million expected CERs by 2007 have been issued in China. This indicates that there is a huge gap between actualized CERs and expected CERs (Huang 2007) in China. Besides, the future of CDM itself is still uncertain under the current post-2012 negotiations. Also, the development of CDM project requires extra investments and capacity building. Third, the marketing and sales of SOF need an extra investment. It is hard to establish the marketing channel all by the energy service company itself (Wang 2008).

4.3 Biomass Collection Chain, Public-Private Partnership and Market Economy Involvement

Biomass collection is a key factor for the operation of the bioenergy project in rural China. In Shanxian case, the logistic chain contains around 50% of the total cost for power generation. It is very hard for the power station to collect biomass resource directly from local villagers due to the high transaction cost. Straw brokers are a feasible way in Shanxian case. Brokers are normally from local areas and have a deep knowledge of the local situation and therefore have a stronger capacity to bargain a good price with villagers. Besides, brokers can work in the villages all the time and this makes it much easier for villagers to sale their straw. Third, brokers have the capacity to store biomass in their own houses or other places in the villages. They usually keep some straw in the harvest seasons when the price is low and sale it in winter. This can save the storage cost of the power station and help maintain a relatively stable supply chain. Fourth, the power station can force brokers to follow certain quality standards which are hard to apply directly on villagers. However, brokers are very likely to organize together as a group to bargain a higher price with the power station. Brokers control the resource and are in a good position of the transaction. For example brokers in Shanxian project therefore consist 15% of the total cost.

Mishan project established a price stimulation scheme to give a lower biogas price for villagers who hand over a certain amount of straw to the biogas station. This is proved to be effective and both the biogas station and villagers can benefit from it. However, for the biomass power generation project, the biomass is used for electricity generation purpose instead of biogas supply for local community which make it not easy to build up the partnership between the station and local villagers.

Besides, two other factors can also impact the biomass logistic chain. The first one is the plantation variety. For example in Hunan Province, the rice harvest seasons are early august and late October (Sino-Danish Project 2008). Also harvest of many other types of straw should be collected in November. Straw collection should avoid these time periods due to the lack of labour. Second one is local infrastructures. To reduce the transportation costs, straw is usually packed up with a high volume and weight in the village level. Road accessing to villages should be built with sand and stone at least. It is great preferable if those local communities have bus connection or dock yard.

According to the analysis of the current systems, it is important to design certain commercial mechanisms to involve local villagers into the biomass collection system. Secondary rebate scheme is suggested here as a good solution. Under this scheme, local people will own certain shares of the bioenergy company by providing the exact amount of straw in a fixed period. Energy companies purchase the straw with a fixed price in the harvest time. Local people can expect a dividend in the end of the year if the company is profitable. This refund mechanism is well recognized in rural China in some other rural industries like honey companies in Sichuan Province (Huang, Tao, pers.comm). However, since almost all the bioenergy projects are in the demonstration level and are not profitable. It is hard to guarantee the dividend with local people at this stage. Project owners have to be very careful to make this cooperative relation with local villagers which may be a big harm for the trust building if no bonuses can be provided.

Besides the refund scheme, "order in" model can be also employed in the collection system. In China, this model has been successfully used in the tobacco industry (Sino-Danish Biomass Energy Project, 2008). Tobacco companies make the contract with each households or farmers in the beginning of the year to purchase their products in the harvest season. This is more suitable for large-size farms in north-east China and specialized households with grain plantation in well developed rural areas. The transaction cost can be highly reduced through the scale ascendency. Through the contracts, both energy company and farm owners can be involved as stakeholders. The biomass can then be fully commercialized in rural China. However, trust building between companies and famers is crucial for the success of the contract.

On the other hand, the development of bioenergy industry in rural China and the related business models of biomass resource collection have a very close relation with the issue on how to help local community in rural China involve into the market economy. The successful cases in this research prove that the involvement into the market economy can help local people increase their cash income (for example the Shanxian case), improve the quality of life (for example the Mishan case) and increase agriculture productivity and achieve a more sustainable rural development (for example the Pingxiang case). There is a great potential that bioenergy development in rural China can help the involvement of market economy if it is organized properly.

However, the rural organization can hardly be organized my local people themselves (Tao, Qing, Wang pers.comm). For example, in GEI case, the initial plan was to give money directly to each household and asked them to work together with the chief of the community to organize an association together by themselves. But it did not work. Local people have the willing to take part in the association because they can get cash flow but no one would like to organize this association because it was just "too much work and trouble".

Also, it is hard to be organized by enterprisers outside their local system. In Shanxian case, for example, straw was collected directly from local community through the collection stations before the beginning of 2007. But the price increased dramatically in one year from 120 Yuan to 250 Yuan. Then the power station have no other choice but hire local brokers to help collect resource and this help maintain the price to around 250 Yuan level in the past half year. Lack of the trust and understanding of local situation are the two main constraints for outside organizations to work in rural China.

The GEI case provides the solution that the third part can play the role to go into the local community to help organize such cooperatives or public-private schemes. Two of GEI's staffs started their program by visiting all households at least twice in the beginning of the projects. During the process of their program, they went to the project village at least one a month to help organize activities, invite biogas technicians or other experts to give training and help the capacity building (Wang, pers comm.).

Comparably, local enterpriser can also play the role by themselves if they know the local situation quite well and maintain the good relation with local people. In Pingxiang case, the local enterpriser successfully becomes the third party to help organize the organic plantation cooperatives. Brokers in Shanxian case can also be considered as the third party to help organize the biomass collection association. However, this is not always the case. For example in Shenlong case, the farm owners did not want to provide their neighbours with the biogas pine system in which case they can even save the initial investments by claim for subsidy from the government. They chose to generate electricity on-site so that they can get rid of the problems of dealing with local people.

There are some barriers for these market economy cooperatives. First, bioenergy project developers, technicians, volunteers, governmental officers can hardly take the responsibility as the third party. NGOs cannot fully involve into the cooperative due the political concern, lack of capacity, and scarcity of professorial social workers. Besides, there is a trial stage for the project development which is important for trust building and deep understanding. But usually project developers do not consider this period into planning.

In a short summary, certain market economy schemes or public-private partnership are needed for the further development of bioenergy in rural China. In general, the cooperatives should be built up together by project developers and local people. Local people should also have a certain share of the ownership. The project developer is in charge of the operation of the project while local people provide the resource like biomass or labour under a fixed price. The profits of the cooperatives should go back to local people as dividend. Besides, to organize the cooperatives or market economy involvement schemes in local community, a third party is usually very helpful and can help to build trust, enhance the understanding of both the industry and local communities, and help the capacity building of the local community.

4.4 Trust Building in the Rural Society

Trust building is crucial for the development of bioenergy business in rural China. First, it is important for the biomass collection. It is a culture in rural China that most of the agreements are achieved through the personal trust and the relations rather than the contract. Without the trust, it is greatly possible that local people will keep on increasing the price of their biomass since it costs almost nothing for them. Also, there is a high possibility that they may delay the payment for the biogas service because they do not think the contract should be followed strictly and it is almost impossible for the service providers to go through legal procedures with individual households (Xu Pers.comm). Since the biomass belongs to millions of individual households in most parts of China. The transaction cost can be very high if there is no trust between local community and the project developers.

Besides, in many cases, local people are also consumers (biogas and organic fertilizer). It is not easy to ask local people change from their convenient energy consumption (it can be the biomass combustion stove, the combustion of coal or even the liquefied petroleum gas or natural gas in some rich areas) to the utilization of biogas unless the local community believes that the bioenergy projects can bring more benefits to them.

The Shanxian provides give a possible solution that brokers can help builds up the trust. Usually brokers are also from the same local community and they are very familiar with the local situation. Also, as brokers they are good at communication and marketing. However, this solution is not good enough to reduce the cost. With the help of brokers, the power station is easier to get the stale resource supply with a good quality.

The Mishan case shows that the setting up energy service station/office in the local community is a possible way to achieve this. Those stations are usually in small scale, typically with one director, one administrative staff and one or two technicians. It is very important that most of the staffs are from the local community with the existing trust. This is a cost-effective way because first, it provides job opportunities for local people which makes the project much more popular; second, all customers know the person who works as a technician and can always find him/her easily, and in many cases, out of the working hours; third, technician living in the local community is especially important if the project is in the remote area with bad road conditions; fourth, the payment for local staff is much cheaper than hiring from outside. It is proved that the local service station can provide good maintenance cost-effectively.

It is also very important to educate local people so that they have the trust on the new facility and technology. In rural China, local people's knowledge about biogas is mainly from the experience of the household biodigester which is not very successful. The household biodigester is considered to be time consuming. People have to spend an extra time to clean the digester and on the maintenance of the whole facility. Therefore, it is very important to educate people the benefits of the community level biogas facilities. Demonstration household is a good way to help. Marketing of the energy service office is also effective because at least people choose to listen carefully to staffs who are from the same community. In practice, demonstration households are usually those staffs' family. The promotion of government is important as well because local people have a belief on the information from official channels.

4.5 Resource Investigation and Planning

Information from the rresource investigation is very important for the pricing determination of biomass and the planning of the whole bioenergy industry. However, there is no national level biomass resource investigation in China. The biomass resource data are calculated based on the agriculture and forestry industry. For example, the total amount of biomass resource for energy purpose is estimated based on the agriculture and forestry production with an experiential ratio (Wang, pers.comm).

But in practice, there is a big gap between the biomass generated from agriculture and forestation and the resource that can be used for modern energy purpose. A big amount of biomass resource is not available for energy purpose under the current market price (NERC 2008). Also, the national bioenergy planning for 2012 is lack of the support from the solid investigation. This leads to the project booming and then a big problem of operation due to the scarcity of the resource. More than 80 large scale biomass power station projects have been approved in one year in 2008 and many small scale biogas projects are also be strongly promoted by regional and local governments. This leads to a rapid increase in demand side and a big gap between the biomass supply and demand.

Besides, the regulation authority of large biomass power stations projects is belongs to the provincial government. In practice, the project is usually proposed by local government and approved by provincial government with a few exceptions of demonstration projects supported directly by the national government. Both provincial and local governments have a strong willing to promote the development of bioenergy project due to the consideration of economic development. First, the direct investment for a large scale biomass power station is usually more than 0.2 billion RMB in China and this can significantly increase the local GDP growth. It is a big drive for local governments in agriculture areas to promote such industrial project. Second, the construction and operation of the project can provide around 1000 job positions (NDRC 2008a) and most of them can be filled in locally. Third, local people can benefit directly from selling biomass which would otherwise be burnt directly after harvest seasons. This brings cash income for local people and significant environmental benefits.

However, since the resource collection radius is more than 100 km currently in China and always covers more than one province, it leads to the resource intensive resource competition. For example in the Shanxian case, the resource collection area covers four provinces. Another extreme example is Suqian biomass project in Jiangsu Province which also belongs to BNE. In its 100 km radius biomass collection area, three similar projects are under construction.

For enterprisers and energy companies, they have an over-confidence on the development of bioenergy, due to the over-estimation and the stimulation. In the past two years, a huge amount of investments flow into the bioenergy industry in China. Most of the project proposals are based on the assumption that 50% of the local biomass resource can be collected with a price less than 250 Yuan/ton. But in the real case, the collection ratio is only 15-20% under the expected price. To maintain the operation of the station, they have to enlarge the collection radium. This increases the operation cost and also exacerbated the resource tension. Besides, they did not consider the social and culture factors in rural China and the high transaction cost. Third, they did not consider the high resource competition in such a short period due to the promotion of renewable energy law and the national subsidy scheme. Fourth, primary movers want to monopolize the market at the early stage. A large amount of money goes into the bioenergy industry and leads to a sharp increase of resource demand in a short period of time and the irrational increase of the biomass price.

4.6 On-grid Electricity Price and Subsidy

The current price determining mechanism according to NDRC's regulation is based on the on-grid electricity price which is mainly determined by the coal-fired power stations of each province. A subsidy of CNY 0.25 Yuan is provided based on that average price (NDRC 2006a). Temporary subsidy can be available in the situation of case by case. This subsidy policy plays an important role in the promotion of bioenergy in rural China.

However, there is a strong argument here that the average on-grid electricity price varies among different provinces and it is a big barrier for the development of bioenergy in some provinces. For example, Xinjiang province has a big potential to develop bioenergy industry because the agriculture in is organized mainly by state-owned farms which can provide a stable biomass supply. But no bioenergy project is organized in Xinjiang because the average on-gird electricity price is only 0.28 Yuan while the average cost for electricity generated from biomass power station is around 0.8 Yuan (Xu pers.comm). Even considering the big support of subsidy, the bioenergy projects in Xinjiang province will still be in deep deficit. Comparably, the average cost in some provinces in South China is more than 0.6 Yuan per kWh and this makes the biomass project profitable if concerning the subsidy plus. However, these provinces are mainly industrial provinces and cannot maintain the biomass supply.

Besides, the subsidy is not from fiscal money but is shared among the provincial grid. This means the consumers in the province take the responsibility to promote the renewable energy industry and pay for the extra money for the energy intensity reduction and environmental benefits. However, most of these provinces are agricultural provinces and it is unfair to ask rural farmers to pay for the problems caused by the industrial provinces.

4.7 Barriers of the Promotion of Bioenergy Business in Rural China

4.7.1 Economic barriers

Even though bioenergy projects are technically feasible in China the progress does not go beyond the demonstration level. Economic barriers exist in the market and delay its further development.

A high initial cost

Key equipments like the boiler of the large biomass direct combustion power station still rely on importation and this leads to the high initial cost. Besides, most of the projects choose the single large combustion boiler technology which also requires a high initial cost. For those large-medium biogas projects, the initial cost is beyond the capacity of the farm owners in most of the case and they cannot get payback in a short period.

Lack of financial resource

Most of the demonstration projects are financed by the government. Since the energy industry is still not fully open to private sectors and international investors, large biomass power stations can only be invested by state-owned energy companies. For the biogas projects, livestock farm owners can hardly get capital investments from banks due to the uncertainty of the new industry. Only a few of them can get support from government if they choose to provide biogas for local community directly. Energy Service Company is also lack of the investment resource. Due to the high risk of a new industry, commercial banks do not provide loans for this kind of projects. The company can get money from inter al investment or from venture capital. But the market is not clear yet.

Renewable energy price

The current renewable energy price in below the electricity cost even including the 0.25 Yuan per kWh subsidy. Temporary subsidy can make some help for the operation of the project but there is a high uncertainty. The subsidy is shared inside the provincial grid and therefore cannot be far beyond the current price level due to the consideration of the sake of fairness.

Resource scarcity

Due to the over estimation of the accessible biomass resource, the capacity of the project has been highly enlarged. This leads to a serious tension between the demand and supply sides and cause the sharp increase of biomass resource

4.7.2 Policy and governmental barriers

Co-firing policy

Co-firing power generation is not included in the renewable law. This delays the development of the co-firing biomass power stations in China which is technically and economically feasible. Besides, this regulation is also a barrier for the private investors. Most of the domestic investors cannot involve into the biomass direct combustion project due to the high initial investment and the policy uncertainty. Co-firing project is suitable for them. But without the subsidy, projects are not profitable under the current price level.

Price determining mechanism

The renewable energy price is based on the average electricity price of the provincial grid. But in practice, the average cost is too low to support the operation of the bioenergy power station in some resource-intensive provinces while in other poor resource provinces the price is high enough to support the development of bioenergy station.

Share the responsibility

The subsidy is shared inside the provincial grid. The bioenergy project is usually built in relatively less developed provinces with a large portion of agricultural population. It is a big issue about justice to ask them burden the higher electricity price which will generate external benefits for the whole country especially for the more developed industrial countries.

Lack of resource investigation

The current planning of using biomass as an energy resource is based on the agriculture and forestry data. The investigation does not consider the accessibility of the resource under the certain price level. This brings a blindness of project planning and authority.

Lack of integrated management

The bioenergy projects are usually approved and regulated by provincial governments. For the economic and social benefits of the project, each province has a strong will to promote its development. But the resource collection area usually covers more than one province and this increases the resource competition and the resource price.

4.7.3 Social barriers

The biomass resource is belongs to individual households in rural China. The transaction cost is very high for the bioenergy company to collect resource from individual households. Besides, people in rural China do not have a strong concern on market economy, and there is a high risk that they will not follow the contract all the time. Also, people in rural China build their trust on the personal interaction and it is not easy for companies from outside to involve into the local community.

5. Conclusion and Recommendations

This research concentrates on the promotion of bioenergy business in rural China, especially the market experiences that can be replicated and scaled up. The purpose of this research is to investigate the current examples of biomass for energy utilization and manure waste to energy facilities in rural China and the emerging market, to analyze barriers for the business and problems in the market. Six empirical case studies are examined in this research, together with interviews, literature reviews and analysis. This part synthesizes the key findings and provides further suggestions for research.

The development of rural bioenergy business can bring benefits to local communities for sustainable development and these activities will be further stimulated by the government. Bioenergy projects, especially biomass power stations, can directly increase the income of local people. Both biomass power stations and biogas facilities bring environmental benefits to the local community. Both of them provide job opportunities for local people. Biogas facilities can also help enhance local people's accessibility to modern energy services and they can stimulate local people's participation into the market economy. The development of bioenergy business will be further promoted by the government and this is written in all the national level planning documents, regulations and the renewable energy law.

Current bioenergy demonstration projects face problems and are not profitable in general. The sharp increase of the biomass resource price makes it hard to be profitable during the operation period. Generators installed for biomass projects are usually too large for the current resource base. The current renewable energy subsidy level is already a good help but still not enough. High initial investment is the bottleneck for the commercialization of projects and the main reason for this is the high technology import cost and the applicability cost due to the equipment maintenance. The grid connection is a challenge for the on-grid power projects due to both technical and socio-economic issues. For the off-grid power projects, they usually cannot be financed by the government and need to search for other investors.

Bioenergy business can hardly work without the involvement of the local community in the market economy and this requires the establishment of local networks and trust building with local people both of which are crucial for the operation of bioenergy business. For biomass power stations, the local people are the main suppliers of the biomass resources. The transaction costs rely on the local network and the trust among these local resource suppliers. For biogas facilities, local people are the main consumers of the biogas and their consensus also relies on trust. Besides, there is a strong interaction between the local community and the external energy companies during the whole process of bioenergy projects and trust is highly required to be built between them.

Both the biomass collection chain and trust building are systematic challenges that require the cooperation of energy companies, local communities and the third party (Co-operatives, NGOs and brokers). According to this research, the professional rural co-operatives are a good model to help local people to be involved in the market economy. For bioenergy companies, the involvement of local people in the market economy is an efficient way to maintain the stability of the biomass resource supply, energy demand and the smooth operation of systems. For local people, the market economy can significantly bring more cash income and a better quality of life. However, private companies lack the capacity to organize local people. The third party can play an important role in this field. The third party can be non-profit organizations with the purpose of poverty reduction or local brokers who are profit oriented.

The Energy Service Company model (ESCO) can play an important role in bioenergy development in rural China, especially for the large biogas power stations. The current waste-to-energy industry faces a dilemma that the best technology is not the preferable choice for developers and the high initial cost is still the bottleneck of the broad commercialization of biogas power stations. According to this analysis, the ESCO model can help solve both of these problems. The energy service company invests on the biogas facilities, provides the service, and shares in the benefits from the waste treatment. Financing ESCO companies is a problem due to the uncertainty and high risks in the new industry. Primary movers can motive the whole industry.

The role of the government is important for the new bioenergy industry in rural China. The renewable energy law and related regulations have already stimulated the development of the whole industry. However, there are still some existing problems. There is no fundamental investigation on the biomass resource accessibility according to the market price. Biomass power stations have been over-promoted without concerns for resource sustainability and technology barriers. The regulation authority belongs to provincial governments and this has aggravated the resource tensions. Besides, the government promotion on demonstration projects to some extent delays the progress of involving private investors in the field. Also, the on-grid electricity subsidy mechanism should be improved in the future.

To enable the further development of bioenergy in rural China, a few suggestions are listed below. These can also be viewed as key research areas.

- The national government should organize a biomass resource investigation as soon as possible. Economic indicators, market conditions and local social and cultural situations should all be involved in the investigation. Modification of the national strategy and related regulations should be made according to the investigation.

- The responsibility of the project authority should be national government with a more strict regulation process. The resource collection radium should be strictly restricted to 50-80 km. The strict regulation should also be put on the total installation capacity of each region.

- The temporal subsidy should be clearer and can be more accessible to primary investors before the start of projects. Coal-firing stations should be included into the subsidy system with the necessary monitoring methodology. Further research can be put on the possibility of separation of coal-fired power price and renewable price and the share of cost among the national grid.

- The professional co-operatives and other forms of local association should be promoted by local government with financial support and capacity building. The local broker system should be organized and supported by the national government. The role of NGO on local poverty reduction and market economy involvement should also be supported by the government.

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Abbreviations

TERMS:

BDCPG	Biomass Direct Combustion and Power Generation
BGPG	Biomass Gasification and Power Generation
CDM	Clean Development Mechanism
IEA	International Energy Agency
MSW	Municipal Solid Waste
NDRC	National Development and Reform Commission of China
PVC	Polyvinyl Chloride

UNITS:

Ha	Hectare
kWh	Kilowatt hour
MW	Megawatt
PJ	Petajoule
sqkm	Square kilometre
Yuan (CNY)	Chinese currency, 1 Yuan ≈ 0.11 EURO

Appendix

Appendix I. List of Interviewees

Name	Interview time	Title	Category
Lu, Hongya	February 20th, 2009	China Project Manager, Institute of Applied Material Flow Management	Academy
Jin, Jiaman	March 2nd, 2009	Director, Global Environmental Institute	NGO
Wang, Yanjia	March 3rd , 2009	Professor, Tsinghua University	Academy
Tao, Kanghua	March 5th, 2009	CEO, Yangzi Delta Consultant	Consulting
Li, Lin	March 5th, 2009	Project Manager, Climate Bridge Co. Ltd.	Consulting
Lin, Xiangjin	March 9th, 2009	Senior Researcher Chinese Academy of Social Sciences	Academy
Jiang, Renan	March 10th,2009	Professor, Nanchang University	Academy
Jiang, Yuanfu	March 14th, 2009	CEO, Poweru Energy Service Co. Ltd.	Industry
Jiang, Dalong	March 17th, 2009	CEO, Dragon Power	Industry
Xu, Tongmao	March 17th, 2009	Vice President, Dragon Power, former director of International Department, NDRC	Industry & Government
Du, Heng	March 30th, 2009	Director, Ecologia Sichuan Office,	NGO
Tang, Ya	March 31st, 2009	Professor, Sichuan University	Academy
Huang, Xiaorui	April 1st, 2009	Expert in rural development and international trading, Freelance	Expert
He, Handong	April 2nd, 2009	Senior Researcher, Biogas Research Institute, Ministry of Agriculture	Government

Wang, Aiming	April 3rd, 2009	Project Manager, Global Environmental Institute	NGO
Hu, Yiwen	April 8th, 2009	Former Director, Guanghua Technology Foundation	NGO
Xiong, Lin	April 9th, 2009	CEO, Shenlong Livestock Co ltd	Industry
Peng, Yuquan	April 15th, 2009	CEO, Pingxiang Taihua Technology Co. Ltd.	Industry
Chen, Zhiping	April 19th, 2009	Senior Manager, Global Environmental Institute	NGO
Zhang, Qi	April 20th, 2009	Former Director, Bohai Security	Financing
Luo, zhigang	April 21st, 2009	Senior Research, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences	Academy
Zhao, Yuxia	April 22nd, 2009	Director of Carbon Department, Sangda Energy Co.ltd	Industry
Tan, Shilei	April 22nd, 2009	CDM Program Manager, Sangda Energy Co.ltd	Industry
Qin, Shiping	April 23rd, 2009	Senior Researcher, Energy Research Institute, NDRC	Government
Li, Junfeng	April 23rd, 2009	Vice President, Energy Research Institute, NDRC	Government
Cai, Changda	May 5th, 2009	ECO, HEEE	Industry
Local Residents	March 26th – April 3rd, 2009	Random Household Visiting, Sichuan	Local Residents
Local Residents	April 6th- 10th, 2009	Random Household Visiting, Jiangxi	Local Residents

Appendix II. List of firms and institutes of this research

Name	Key Roles	Category
Dragon Power C.,Ltd.	Boiler Manufacture & Power Station Investment	Industry
Wuxi Huangguang Boiler C.,Ltd.	Biomass Boiler Manufacture	Industry
Hangzhou Energy and Environment Engineering C.,Ltd.	Biogas Facility Manufacture & Project Construction	Industry
Qingdao Tianren Energy C.,Ltd.	Biogas Facility Manufacture & Project Construction	Industry
Henan Sangda Energy C.,Ltd.	Biogas Facility Manufacture & Project Construction	Industry
Guangdong Kangda Energy C.,Ltd.	Biogas Facility Manufacture & Project Construction	Industry
Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences	Technology Development & Energy Strategy Research	Academy, Technology Development
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Energy Research Institute, NDRC	Policy-making	Government

Appendix III. The Renewable Energy Law (Key Chapters)

Chapter 1. General
Article 1—In order to promote the development and utilization of renewable energy, improve the energy structure, diversify energy supplies, safeguard energy security, protect the environment, and realize the sustainable development of the economy and society, this Law is hereby prepared.

Article 2—Renewable energy in this law refers to non-fossil energy of wind energy, solar energy, water energy, biomass energy, geothermal energy, and ocean energy, etc.

Application of this Law in hydropower should be regulated by energy authorities of the State Council and approved by the State Council.
This Law does not apply to the direct burning of straw, firewood and dejecta, etc. on low-efficiency stove.

Article 3—This Law applies to territory and other sea area of the People's Republic of China.

Article 4—The Government lists the development of utilization of renewable energy as the preferential area for energy development and promotes the construction and development of the renewable energy market by establishing total volume for the development of renewable energy and taking corresponding measures.

The Government encourages economic entities of all ownerships to participate in the development and utilization of renewable energy and protects legal rights and interests of the developers and users of renewable energy on the basis of law.

Article 5—Energy authorities of the State Council implement management for the development and utilization of renewable energy at the national level. Relevant departments of the State Council are responsible for the management of relevant development and utilization of renewable energy within their authorities.

Energy authorities of local people's governments above the county level are responsible for the management of the development and utilization of renewable energy within their own jurisdiction. Relevant departments of local people's governments above the county level are responsible for the management of relevant development and utilization of renewable energy within their authorities.

Chapter 4. Promotion and Application.
Article 13—The Government encourages and supports various types of grid-connected renewable power generation.

For the construction of renewable energy power generation projects, administrative permits should be obtained or filing should be made in accordance with the law and regulations of the State Council.

In the construction of renewable power generation projects, if there is more than one applicant for project license, the licensee should be determined through a tender.

Article 14—Grid enterprises should enter into grid connection agreement with renewable power generation enterprises that have legally obtained administrative license or for which filing has been made, and buy the grid-connected power produced with renewable energy within the coverage of their power grid, and provide grid-connection service for the generation of power with renewable energy.

Article 15—The Government supports the construction of independent renewable power systems in areas not covered by the power grid to provide power service for local production and living.

Article 16—The Government encourages clean and efficient development and utilization of biological fuel and encourages the development of energy crops.

If the gas and heat produced with biological resources conform to urban fuel gas pipeline networks and heat pipeline networks, enterprises operating gas pipeline networks and heat pipeline networks should accept them into the networks.

The Government encourages the production and utilization of biological liquid fuel. Gas-selling enterprises should, on the basis of the regulations of energy authorities of the State Council or people's government at the provincial level, include biological liquid fuel conforming to the national standard into its fuel-selling system.

Article 17—The Government encourages workplaces and individuals in the installation and use of solar energy utilization systems of solar energy water-heating system, solar energy heating and cooling system and solar photovoltaic system, etc.
Construction authorities of the State Council should cooperate with relevant authorities of the State Council in establishing technical economic policies and technical standards with regard to the combination of solar energy utilization system and construction.

Real estate development enterprises should, on the basis of the technical standards in the previous paragraph, provide necessary conditions for the utilization of solar energy in the design and construction of buildings.

For buildings already built, residents may, on the condition that its quality and safety is not affected, install solar energy utilization system that conform to technical stdnards and product standards, unless agreement has been otherwise reached between relevant parties.

Article 18—The Government encourages and supports the development and utilization of renewable energy in rural areas.

Energy authorities of local people's governments above the county level should, on the basis of local economic and social development, ecological protection and health need, etc., prepare renewable energy development plan for the rural area and promote biomass energy like the marsh gas, etc. conversion, household solar energy, small-scale wind energy and small-scale hydraulic energy, etc.

People's government above the county level should provide financial support for the renewable energy utilization projects in the rural areas.

Chapter 5 Price Management and Fee Sharing
Article 19—Grid power price of renewable energy power generation projects should be determined by the price authorities of the State Council in the principle of being beneficial to the development and utilization of renewable energy and being economic and reasonable, where timely adjustment should be made on the basis of the development of technology for the development and utilization of renewable energy. The price for grid-connected power should be publicized.

For the price of grid-connected power of renewable power generation projects determined through tender as stipulated in the 3rd paragraph of Article 13 hereof, the bid-winning price should be implemented; however, such a price should not exceed the level of grid-connected power of similar renewable power generation projects.

Article 20—The excess between the expenses that power grid enterprises purchase renewable power on the basis of the price determined in Article 19 hereof and the expenses incurred in the purchase of average power price generated with conventional energy should be shared in the selling price. Price authorities of the State Council should prepare specific methods.

Article 21—Grid connection expenses paid by grid enterprises for the purchase of renewable power and other reasonable expenses may be included into the grid enterprise power transmission cost and retrieved from the selling price.

Article 22—For the selling price of power generated from independent renewable energy power system invested or subsidized by the Government, classified selling price of the same area should be adopted, and the excess between its reasonable operation, management expenses and the selling price should be shared on the basis of the method as specified in Article 20 hereof.

Article 23—The price of renewable heat and natural gas that enters the urban pipeline should be determined on the basis of price management authorities in the principle of being beneficial to the development and utilization of renewable energy and being economic and reasonable.

Chapter 7 Legal Responsibilities

Article 24—The Government budget establishes renewable energy development fund to support the following:

1. Scientific and technological research, standard establishment and pilot project for the development and utilization of renewable energy;
2. Construction of renewable energy projects for domestic use in rural and pasturing areas;
3. Construction of independent renewable power systems in remote areas and islands;
4. Surveys, assessments of renewable energy resources, and the construction of relevant information systems;
5. Localized production of the equipment for the development and utilization of renewable energy.

Article 25—Financial institutions may offer preferential loan with financial interest subsidy to renewable energy development and utilization projects that are listed in the national renewable energy industrial development guidance catalogue and conform to the conditions for granting loans.

Article 26—The Government grants tax benefits to projects listed in the renewable energy industrial development guidance catalogue, and specific methods are to be prepared by the State Council.

Article 27—Power enterprises should authentically and completely record and store relevant materials of renewable energy power generation, and should accept the inspection and supervision of power supervisory institutions.
Power supervisory institutions should do the inspection in accordance with stipulated procedures, and should keep commercial secret and other secret for inspected units.

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