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Energy input and output of a rural village in China – The case of the "Beijing Man village"/ District of Beijing

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Abstract

The rapid development of the economy has created an increasing demand for energy in China. The limited resources of fossil energy are a risk for the development of China. Sustainable agriculture with biomass energy - as done in developed countries like Germany - is an option to reduce these risks. In China, agriculture is not energy efficient, and the intensive farming is not sustainable. The scientific challenge is to develop sustainable farming systems which can fulfill national food security, food safety and considerable renewable energy production without harming the environment, and are acceptable to the people and the economy. The protection and intelligent utilization of resources is the core of rural village development.

To explore the potential of recent Chinese agriculture for the development towards a multi-functional farm for food and energy production, a village in the adjacent area of Beijing has been selected: the "Beijing Man village". About 1,900 people live in the village and 140 hectares of the 240 hectare total land are available for farming. The major agricultural activity is pork production (capacity of 10,000 pigs per year) and dairy farming (40 dairy cows).

In 2004, the energy input and output of this village was evaluated and taken as a basis for a model of sustainable farming for food and biogas production. The study explored that the gross energy production from crops in the "Beijing man village" was about 19,103 GJ/year. It was obvious that the crop production was not sufficient for the feed demand of the animal husbandry (pigs and cows). 60 % of the corn used as feed stuff was purchased on the market. The reason was, that the purchasing of corn was cheaper than the own production. The low competitive crop production due to the low efficiency resulted in the decrease of cultivated crop land from 140 ha to 80 ha in the past four years (two harvests per year).

On the other hand, there was much more manure produced as suitable and applicable for crop production. Therefore manure was exposed in open air in a pond like waste. This is risky for public hazards like ground water contamination and zoonosis diseases. Therefore the farming system is not sustainable, risky and not efficient. There is a potential of the optimization of the cropping and animal husbandry interaction as well as the development of renewable energy production in the village. The main development chains are the improvement of the energy efficiency of crop production, the reduction of animal husbandry to a sustainable animal-land-ratio and the introduction of biogas production with manure and cropping by-products.

Keywords: China, Energy Farming, Farm Energy Input-Output, food security and safety

Zusammenfassung

Energie-Input- und -Output-Analyse eines ländlichen Dorfes in der Region Beijing/China

Energie ist eines der größten Probleme in der Entwicklung Chinas. Dieses gilt auch für den ländlichen Raum. In einer Studie in einem Dorf in der Nähe von Beijing wurde ermittelt, wie hoch der jährliche Energie-Input und Energie-Output ist. In dem Dorf „Beijing Man village" leben rund 1.900 Menschen und es stehen 140 Hektar von insgesamt 240 Hektar Land für den Pflanzenbau (Soja, Mais, Weizen) zur Verfügung. Es sind zwei Ernten pro Jahr möglich. Wichtigste landwirtschaftliche Produktionszweige sind die Schweinehaltung (Kapazität von 10.000 Mastschweine pro Jahr) und 40 Milchkühe. In der Studie wurden die Energiebilanzen der Pflanzen- und Tierproduktion als auch der Energiebedarf der privaten Haushalte für das Jahr 2004 per Fragebogen und Analysen vorliegender Dokumente ermittelt.

Es stellte sich heraus, dass im Pflanzenbau im Jahr 2004 auf 80 Hektar mit zwei Ernten rund 19.103 GJ Energie in Form von Erntegut (Getreide, Stroh) produziert wurden. Der Pflanzenbau war bei weitem nicht in der Lage, den Futterbedarf der Tierhaltung (Schweine, Milchkühe) zu liefern. 60 % des Futters wurden auf dem Markt zugekauft. Grund war der Preis. Es war billiger, Futter zuzukaufen als selber zu produzieren. Aus diesem Grund wurde in den letzten Jahren der Pflanzenbau von 140 auf 80 Hektar eingeschränkt.

Wegen des Ungleichgewichtes in Futterproduktion und Futterverbrauch fiel wesentlich mehr Wirtschaftsdünger an, als im Ackerbau verwendet werden konnte. Die Gülle wurde in offenen Erdgruben aufgefangen und teilweise in Gewässer oder einfach auf Ackerflächen geleitet. Dieses bedeutet eine hygienische Gefahr sowohl für die Menschen (Zoonosen) als auch für die Tierhaltung. Der Wirtschaftsdünger wird gegenwärtig als Abfall verstanden und behandelt. Dabei stellt es ein großes Reservoir an Biomasse für die Energieproduktion dar. Durch die Produktion von Biogas wäre es möglich, den Energiebedarf der Landwirtschaft und der privaten Haushalte zu decken.

Schlüsselworte: China, Energie-Input und -Output, Landwirtschaft, Biogas

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1 Introduction

Despite the fact that China is one of the biggest economies in the world in terms of GNP – showing enormous economic growth in the past decade – China is still a country in transition. 80 % of the population lives in rural areas. There is a need for rural development to give people a chance for income and wealth. For example, in the year 2000, the average rural income per capita was 2,401 Yuan (290 US-$) but in the cities 6,306 Yuan (762 US-$) (Tso 2004) (1 US-$ = 8.28 Yuan in 2000). Between 1991 and 2000, the annual growth rate of real income was 5.7 % in rural areas, but 6.9 in urban areas (Huang & Rozelle 2004). Currently, many young people, but even older persons, leave the remote rural areas to find jobs and better living conditions in the – more and more crowded – cities.

Energy shortage is one of the bottlenecks of economic development and improved living conditions in rural villages and small town (Sun 2004). The rural village faces pressure for social development through economic growth on the one hand, and environmental protection on the other hand. It is already apparent that a part of intensive agriculture (high input - high output) in China is evident and endangers the natural resources, and last but not least, the national food safety and security in the future (Pan 2005). Since the multi-functional demands and expectations for the future of farming in China are not a contradiction, the scientific challenge is to develop sustainable farming systems which can fulfill national food security, food safety and considerable renewable energy production without harming the environment, and that are socially and economically acceptable.

Sustainable agriculture has a long tradition in China. Many small scale farms throughout the country work more or less in harmony with the local natural resources. The government has supported the development of these systems to be even more efficient and environmentally sound. Biogas production was always a part of this development. For example, already in the 1950s, Mao ZeDong had forced farm communities to build small biogas facilities to produce gas for home purposes (Zhou 2004). Therefore farm-based biomass production for energy purposes (energy farming) is considered an option to take part of the economic growth.

Recently, the Chinese government launched a national program to develop energy farming in China on several million hectares of land (Sun et al. 2004). To avoid a conflict with the major function of agriculture in China, the production of food, non-agricultural areas like deserted mountains and wastelands are foreseen for the production of biomass. Nevertheless, the sustainable biomass production on a farm would be more suitable because they are more productive and closer to the locations where energy is needed. To avoid the conflict with food production, the biogas production out of manure and by-products of plant production and food processing could be a solution.

Figure 1:
The settlement of "Beijing Man village" (in front the pig stables)

„Beijing Man village“ is a typical rural village in the intensive agriculture belt around the capital Beijing (Figure 1). This village is located in the area where the oldest human bones in China were found (Beijing man) and because of this, the area is on the list of the UNESCO world heritages. This village is especially supported by the Beijing city government to improve production and efficiency through better technology (farm machines, greenhouses, irrigation). Even a biogas reactor was funded and established, but still does not work. Nevertheless, the agriculture productivity per person in this village is still low (ZKCS 2004). This is a typical problem in rural villages in China.

To understand the limiting factors for development in such villages, a study was carried out in 2004. The study focuses on the energy input and output, and the potential of sustainable biogas production. A target of the case study was to design more successful development strategies for sustainable multi-functional farming systems (food and energy).

2 Sustainable food and energy farming in China

Sustainable Farming and Biomass Energy Farming are two trends of future agriculture which are receiving increased attention all over the world (ENEL 1996, OECD 1997, Yang 2004, Paulsen & Rahmann 2004). The social, ecological and economical benefits of sustainable farming are the reasons for this attention. In China, the ecological impact of intensive agriculture (high input – high output) is enormous and endangers natural resources as well as national food safety and security in the future.

Growth in chemical fertilizer consumption has increased 21-fold since 1949. Pesticides amounts of inputs applied increased from 733 tons to 1,275 tons from 1990 to 2001. Per hectare of cropland, 21 kg of chemical fertilizer and 1.5 kg of pesticide inputs are used annually. The limited availability of cropland influences the food production system. For example in 1999, about 1.4 tons of crops per capita have been produced in Germany but only 0.476 tons per capita in China (WRI 2005). The desert encroaches every year with increasing rates. The crop land is diminishing rapidly to 0.08 ha per capita and year (2000). Desertification claimed 156,000 hectares of land annually in the 1950s, 210,000 hectares every year in the 1970s and 1980s, and in the 1990s a total of 246,000 hectare of crop land was lost annually (Deng 2002). In the last 50 years about seven million hectares or nearly 6 % have been lost for food production. Nowadays, one third of China is desert.

Today about 400 (7.7 %) of the native vertebrate species of China are endangered. Quantity and quality of water and farm land are the limiting factors for Chinas future, particularly in food production. China is first in water consumption and pollution. About 7.3 % of China’s irrigated area is watered with untreated sewage water from cities and industrial regions. 5.3 million hectares of cropland in China are damaged by air pollutants (Liu 2003). One third of all rivers in China are polluted, 90 % of the rivers in the cities as well (Pan 2005).

On the other hand, the fast growing economy has an increasing demand for energy. China is facing the severe challenge of the energy shortage. There is an enormous gap between the energy reserves in the next decades (Sun et al. 2004). The degree of petroleum imports is rising. In 2004, 174.7 million tons of crude oil have been produced in China, while the volume of consumption of petroleum increased sharply to 300 million tons. The Chinese net import of crude oil reached 117 million tons in 2004 (Cao 2005). The volume of coal consumption has already accounted for more than 75 % of the total energy consumed in China. This is three times higher than the world average (Li 2005). According to the coal survey data, the coal resources of our country can be utilized for 150 years at most (Sun 2004).

Sustainable farming, in combination with energy production, is considered as an option to take part of the economic growth. To bridge the gap between these demands and the expectations for future farming, the scientific challenge is to develop sustainable energy farming systems which can fulfill national food security and food safety needs and produce considerable renewable energy without harming the environment, and are accepted by economically and socially (Shi 2004).

2.1 Patterns of ecological agriculture and livestock farming in China

Ecological agriculture in China is not directly comparable with Western concepts. With the specific problems and circumstances, special ecological farming systems were already designed in the 1980s to develop sustainable ecological farming in China. Suitable traditional agriculture patterns are integrated with modern knowledge coming from sciences and technology.

Different sustainable agriculture systems have been established in more than 2,000 villages in regions with different ecological framework conditions and socio- economic levels throughout China. 10 categories with 34 sub categories were selected from 370 systems. The 10 categories of sustainable agricultural systems (see list below) have been established throughout China (MAPR 2003):

- “four in one” (that is greenhouse, pig, toilet and biogas assembled in one system) ecological family in the north of China,
- “pig-biogas-orchard” (pig fattening, biogas pond and fruit tree system) ecological village in the south of China,
- agronomy-forestry-livestock combined ecological area in the plains,

- grassland sustainable utilization in China,
- ecological planting and corresponding technology,
- ecological farming and corresponding technology,
- ecological fishery and corresponding technology,
- ecological agriculture in the mountainous areas and corresponding technology,
- ecological agriculture facility,
- sight seeing ecological agriculture and management.

All these different sustainable systems have been intensively evaluated. The most successful und popular farming systems were the "four-in-one" in Northern China and the "pig-biogas-orchards" in Southern China. There are about 0.3 million and 1.7 million households using theses models, respectively (Li 2003).

In 2001, based on the experience from the last decades, the Ministry of Agriculture launched a "bio-household programme". About 1.4 billion Yuan (169 million US-$) has been invested in 8,826 villages to benefit from the programme (Li 2003).

2.2 Energy crop plant farming potential

At present, there are no crops cultivated for energy purposes on arable land in China. However, energy crops like sweet sorghum, trees, sweet beet etc. are cultivated by governmental initiatives on fallow land what is not used for food crop cultivation (mountain areas, river and lake banks) in selected areas (Osten 2004). The rate of forest-covered land rose from 8 % to 16 % from the 1980s to 2003 (Luo 2004). The area of fuel forest increased to 6.4 millions ha in the same period.

The Chinese government is aware about the potential and advantages of sustainable energy production on environmentally friendly farms. A biomass energy development plan for agriculture, forestry and industry was launched in 2005 (14th meeting of 10 National People's Congress (NPC) 2005; 10NPC/14, 2005). One part of this programme wants to force the efforts to develop sustainable farms with improved energy efficiency in food production. The second part wants to introduce the production of renewable energy into agriculture. The governmental programme has the target to produce 100 million tons of biomass energy in 2010 (Kuang 2004).

2.3 Biogas production in China

Besides biomass from fallow land, the by-products of crop farming and food processing as well as manure from animal husbandry are an excellent resource for biogas production. Already in 1979, the Ministry of Agriculture founded a Biogas Institute (BIOMA) in Chengdu. The Biogas Research and Training Center (BRTC) was founded in 1981 at the same place.

Because of the long tradition of biogas in China, adapted technologies for biogas production are available. The most popular biogas reactors have a size of 8 m^3 and use organic residues from the farm. The importance of biogas production is obvious in South-West China. Nowadays, 4.5 giga-m^3 of biogas is produced annually. This biogas is produced by 13 million households with small scale biogas reactors (3.3 giga-m^3). The small scale biogas production does substitute an equivalent of 0.23 hectare for firewood production (Li 2003). Further 2,200 units of middle sized livestock farms (manure) and industrial plants (wastewater) produce 1.2 giga-m^3. At the end of 2003, only 2,124 bigger and more efficient biogas plants could be found throughout the country (Li 2004).

The production of agriculture by-products (fresh matter) is about 3.5 billion coal equivalent (CE). This is compiled by the single values coming from animal manure (2.6 billion CE; see Table 1), crop straw (0.65 billion CE), vegetable by-products (0.1 billion CE), village garbage and

Table 1:
Amount of fresh manure from large-scale livestock farming and biogas production potential in China, 2002

Area	Amount of pig manure/ mio tons	Amount of chicken manure/ mio tons	Amount of cattle manure/ mio tons	Total	
				Amount/ mio tons	GE mio m^3
China total	29.2	6.9	13.1	49.2	2,723
Beijing	1.5	0.6	1.4	3.4	179
Heibei	1.8	0.2	1.4	3.4	173
Shanghai	2.3	0.8	0.3	3.3	203
Zhejiang	2.6	0.2	0.1	2.9	173
Fujian	2.5	0.2	0.3	2.9	171
Shandong	1.4	1.0	0.6	3.0	176
Henan	2.7	0.6	0.4	3.6	214
Guangdong	5.8	1.1	0.3	7.1	432

GE = gas equivalent, fresh pig manure: 1 tons = 60 m^3, fresh chicken manure: 1 tons = 68 m^3, fresh cattle manure: 1 tons = 58 m^3
Source: Lin Cong, et al. 2004

human waste (0.25 billion CE), offal of meat-packing industry and crop processing industry (0.15 billion CE), forestry residues (0.05 billion CE) and other kinds of organic wastes (0.05 billion CE). This organic matter has the capacity of 5.4 million tons of fertilizer (N: 2.26 million tons, P_2O_5: 0.46 million tons, K_2O: 2.72 million tons) (Sun 2004). This enormous energy and fertilizer potential is not used efficiently (Luo 2004, Luo et al. 2004). Only with the wastes of the large-scale livestock farming, it is possible to produce about 2.7 billions m^3 biogas (Lin 2004).

Apart from the national perspective, the general advantages of biogas production are, that the farmers can use their own farm stable manure or slurry and also other residual products such as clover grass, straw or organic material of intercropping for energy production. Some major questions arise with these figures:

- Question 1: How much energy is used or even produced on a typical farm in China?
- Question 2: How much energy is used by rural families?
- Question 3: What is the quality of manure and other farm by-products as fertilizer?
- Question 4: How could biogas production improved in such a village?

A case study was carried out in 2004 to give a first impression of answers to these questions.

3 Methods

3.1 The "Beijing Man village"

"Beijing Man village" lies 46 km south west of China's capital, Beijing City. It is a part of the town Zhou Koudian (Figure 2). The area is famous in the world for the eldest human bones found in China, the "Beijing man". The bones are 500,000 years old and were found in 1929, just 2 km far from the "Beijing Man village" (ZKTCC 2004). The area is listed as world heritage by the UNESCO.

In 2004, 1,945 people in 761 families were living in "Beijing Man village". The surrounding area is hilly, but the village itself and its farm land are flat. From the 240 hectare total surface of the village, 140 ha farm land is available for crop cultivation. The soil texture is clay sandy soil with good production potential. The average annual rainfall is 580 mm. Most of the rainfall is in June to September (2-3 % in winter, 9-10 % in spring, 74-75 % in summer, 13-14 % in autumn). The average annual temperature is 12 °C. In winter the temperature can go down to -10 °C and in the summer can exceed 30 °C. The growing period for crops is between April and November and about 180 to 200 days. Wheat, soybeans and maize are cultivated. Usually, wheat is seeded in October and harvested in May of the next year, than soybeans or maize are seeded in June and harvested in October. Water is supplied by rainfall and irrigation.

Animal husbandry with pigs and dairy cows is more important than crop farming. Usually there are about 340 sows, 1,050 fattening pigs and 40 dairy cows. All animals are kept indoors and fed mainly with purchased feedstuffs. The husbandry conditions can be described as intensive on a medium technical level (high input - medium to high output). A biogas plant was established in 2003 but is still not running because of lack of necessary equipment and gas pipes connected to the households. Numerous greenhouses are in the villages, but not in production actually. Only some are in use by private persons.

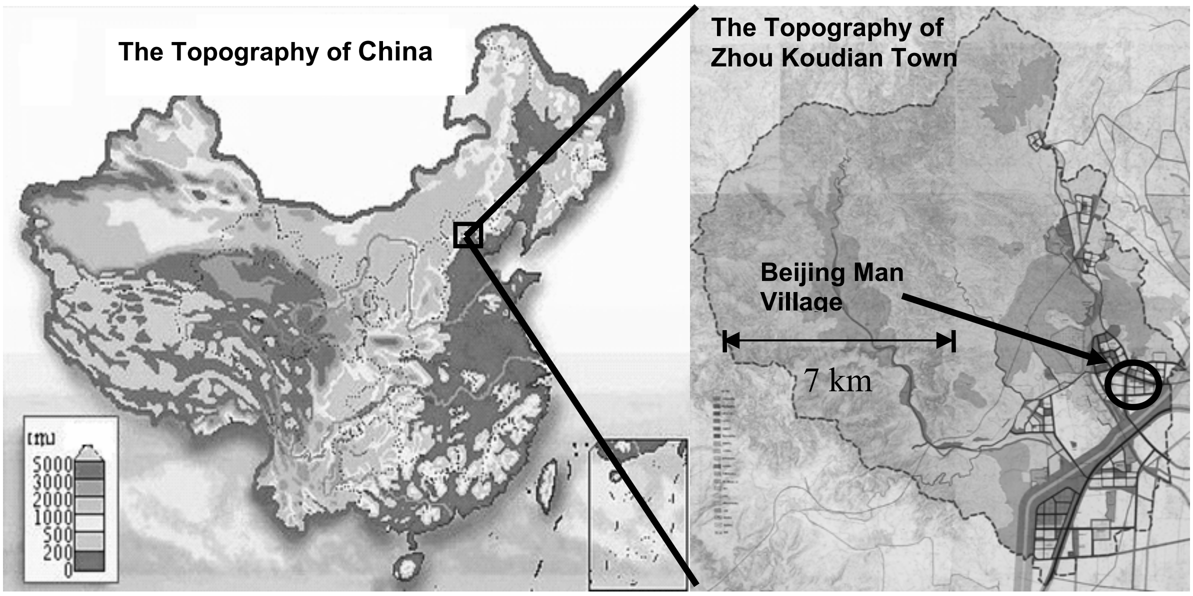

Figure 2:
"Beijing Man village" location

The living standard in the village is high compared to other rural villages in China. The houses are modern and established in the last 10 to 20 years. There is electrical power supply, tarred roads, piped water supply, social infrastructure like schools, doctors, markets for daily consumer goods and food, working places in industry and public services available. The land belongs to the government and the farm land is managed by the village as a cooperative and not by individual families.

3.2 Methods and Data Collection

The study shall evaluate the gross and net energy production and utilization of crop production, animal husbandry and private households to analyse the potential of energy efficiency and the biogas production capacity of the village as an example of similar villages in the surrounding area of Beijing. Workshops and personal interviews with the use of structured questionnaires were used to gather the data.

Workshop: The workshop was to introduce the project of the College of Resource and Environment of the China Agriculture University (CAU) to develop the biogas production in the "Beijing Man village". The half day workshop was held in the meeting room of the local government on December 12th, 2004. The participants of the workshop were selected by the governmental authorities of Zhoukou village. About 10 people attended the workshop: the principal of "Beijing Man village", three other village men (stake holders), governmental representatives and members of the College of Resource and Environment of the CAU. At the workshop, the representatives of the CAU received general information about agricultural and resident living conditions in the village, as well as the geography, natural characteristics, economic, cultural information and so on. The data came from local government statistics. From the village and local principal, information about the history, status and development plan of this area have been collected. The participants were introduced to a plan to develop and improve sustainable biogas production in the village as a case study. It was stated that there will be a study about the energy consumption of the households and the food structure conducted in the village in the coming months.

Questionnaire: According to the planned project, and with the use of the statistical data from the local government, a questionnaire has ben designed to gather information on private households and farming activities in "Beijing Man village". A complete inventory was prepared for private households, livestock keeping and crop production. The questionnaire includes questions on planting (crop production), breeding (animal husbandry) and the residents (the people). The questions about crop production did include the production pattern, the kind of crops, the cultivated land, the input (seed, fertilizer, machinery, fuel, labour, pesticides) and output (straw, feed and food). The questions about animal husbandry included the management of the animals, breeding, input of feed, grass, feed quality, electricity, labour input, animal drugs and so on, as well as the productivity. The questions of the household survey included the daily consumption of food and utilisation of energy, the income and other payments. All these questions were sent randomly to 80 families. These families were interviewed by scientists of CAU. The people answered the questions verbally. Therefore a risk of wrong information exists. This is the general procedure for information gathering and data quality in China.

The information about the biogas plant at the village was collected from the report of the development project funding the establishment of the plant. At the village of Nan Hanji – near the "Beijing Man village" – information was gathered about the results of a running biogas plant on a poultry farm. The data were gathered from January to December, 2004.

3.3 Calculations

The energy input and output of the crop, animal and people subsystems were analysed separately. To compare the several sources of energy,

- industrial energy (mineral fertilizer, pesticides, and fuel) and
- biological energy (human labour, seeds, livestock, manure)

Table 2:
Energy equivalent of different input and output values

Item	Unit	Energy value in KJ per unit
Human labour	Adult man (days) worked for 8 h	12,600
Electricity	KWh	3,598
Coal	Kg	29,288
Pork	Kg	25 921
Milk	Kg	3,221
Muck	Kg	2,025
Seed	Kg	15 899
Fuel	Kg	43,514
Chemical fertilizers		
- N (pure)	Kg	92,048
- P (pure)	Kg	13,389
Pesticide (equivalents)	Kg	1,020,896
Wheat	Kg	15 732
Organic fertilizers	Kg	2,025
Corn	Kg	16,527
Soybean	Kg	20,669
Wheat straw	Kg	13,729
Corn straw	Kg	14,356
Soybean straw	Kg	15 080
Feed	Kg	12,612

Source: Luo 2001

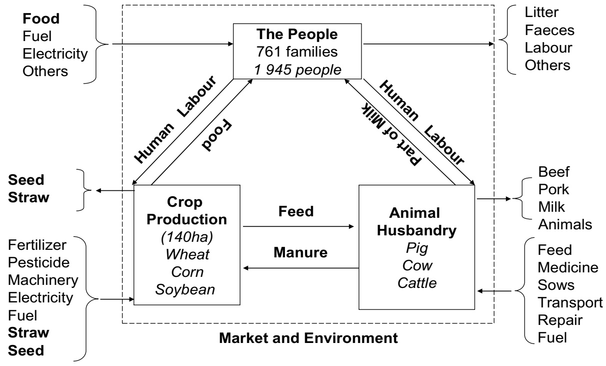

Figure 3:
Model of recent farming system of "Beijing Man village"

have been defined and used for comparison. The output of the farms was calculated on the basis of production yields. The physical quantities of input and output were converted into energy equivalents. The energy equivalents of the various energy sources are taken from Luo (2001; see Table 2).

4 Results

The study is focused on the energy flows of the crop production, animal husbandry and people living in "Beijing Man village" as an example of an intensive farming system in the area surrounding of Beijing capital. The results of the study carried out in 2004 /05 in the village are presented in these three system elements. The recent links of material, energy and labour flowing between crops, livestock and people can be described as designed in the model shown in Figure 3.

4.1 Energy input and output of the subsystem "crop production"

In 2004, only 80 ha (utilized farm land) of the 140 ha farm land have been used for cropping. Two harvests are done. The first crop was wheat (*Triticum aestivum*) and the second crops were corn (*Zea mays;* 33 ha) and soybeans (*Glycine max;* 47 ha). The crop planting and harvesting were done by machine every year. The village community council manages the machine and person arrangements. The crop production has two sources of energy input: the biological energy input (human labor, seed and organic fertilizers) and the industrial energy input (field implements, electricity, fuel, chemical fertilizers, pesticides, etc.). The energy output includes crops and straw (Table 3).

With 30.38 GJ/ha/year, organic fertilizer had the biggest contribution to energy input (56.64 GJ/ha wheat, 75.12 GJ/ha corn and 47.94 GJ/ha soybean; according to the yield of 3.6 tons/ha wheat, 4.5 tons/ha corn and 2.3 tons/ha soybean). Chemical products (14.42 GJ/ha/year) and field implements (9.4 GJ/ha/year) followed. Wheat,

Table 3:
Total energy input and energy output of arable land in the "Beijing Man village" in 2004

Item	amount	Energy (GJ/year)*	Energy GJ/ha crops/year**
Energy input		9,489	59.31
Industrial energy input:		3,973	24.83
Field implement*	0.418 MWh	1,504	9.40
Electricity	0.113 MWh	407	2.54
Fuel for machinery	1,700 kg	74	0.46
Chemical fertilizers			
- N (pure)	17.00 tons	1,565	9.78
- P (pure)	13.29 tons	178	1.11
Pesticide (equivalents)	240 kg	245	1.53
Biological energy input:		5 516	34.48
Human labour	18,000 days	227	1.42
Seed	27 tons	429	2.68
Organic fertilizer	2,400 tons	4,860	30.38
Energy output per crop		19,103	119.39
Wheat (80 ha)	288 tons	4,531	56.64
Corn (33 ha)	150 tons	2,479	75.12
Soybean (47 ha)	109 tons	2,253	47.94
Wheat straw (80 ha)	297 tons	4,078	50.98
Corn straw (33 ha)	206 tons	2,957	89.61
Soybean straw (47 ha)	186 tons	2,805	59.68

* Energy demand estimated on the basis of Luo 2001
** Average energy of production of the cultivated crops: (two cultivations per ha and year): 80 ha wheat, 33 ha corn, 47 ha soybean = 160 ha cultivation.

corn and soybean straw had the most relevant energy output in the system (50.98 GJ/ha wheat straw, 89.61 GJ/ha corn straw and 59.68 GJ/ha soybean straw). The total input-output energy ratio of the crop production was 0.497; the efficiency was just 2.01 (output/input).

In 2004, the total energy input of the arable farming in “Beijing Man village” was 59.31 GJ per ha. This is higher than An (1996) found in the Yaojin village (South of China, 32.81 GJ/ha), Li (1997) in Wang Donggou (West of China, 36.21 GJ/ha) and Song (1995) in the Xiaodiantou village (North of China, 38.7 GJ/ha). The average yield in crop production in “Beijing Man village” (wheat: 3.6 t/ha, corn: 4.5 t/ha, soybean: 2.3 t/ha) was lower than the average figures for China (wheat: 5.25 t/ha, corn: 12 t/ha, soybean: 3.3 t/ha; Shi 2004).

4.2 Energy input and output of the subsystem “Animal husbandry”

The most important livestock husbandry in “Beijing Man village” is an intensive pig farm. The pig production figures are: 300 sows, 40 replacement sows, 10 boars, 10 piglets per litter, mortality rate 10 %, all piglets are fattened at the farm. Actually, about 5,000 pigs are produced per year. The fattening period is 180 days, the feed conversion rate 4 kg feed per 1 kg live weight gain. Furthermore there are two cattle farms with together 40 milk cows and 8 young cattle. They produce 146 tons of milk per year (3,650 kg/cow/lactation$_{305\ days}$).

The animal husbandry is intensive and practiced indoors. Feedstuff for the pigs and cattle is corn, soybeans and industrial concentrates. This is produced on own fields (40 %) or is purchased (60 %). Roughage for the dairy cattle is soybean and corn straw coming from the cropping. Manure from animal husbandry is stored in open ponds and is used mainly as organic fertilizer in crop farming and a little in vegetable production (greenhouses). The input of labour, feed, electricity, fuel and repairs is high (Table 4). The highest biological energy input was feed with 16,690 GJ/year (51% of total energy input). The highest industrial energy input came through pharmaceuticals with 3,954 GJ/year for cost of 54,000 Yuan (6,521 US-$) for preventing disease (12 % of total energy input). The output of the livestock husbandry is pork, milk and manure. The yield of the livestock in system was the highest in pork being 8,100 GJ/year followed by milk (only 470 GJ/year). The yield of by-products was the highest in swine manure, being 2,954 GJ/year, followed by dairy cow manure (423 GJ/year).

In 2004, the feed and straw for the animal husbandry had an energy value of 21,930 GJ. This was not all produced by own cultivation. In 2004, the energy of the own produced crops was 19,130 GJ. The feedstuff demands in animal husbandry were 1,323 t of feeding concentrates (for pigs and cattle) and 365 t of straw for roughage for cattle. The farm own concentrate production was just 547 t (-776 t deficit). With 689 t of straw there was enough roughage for cattle available (+324 t above demand).

Table 4:
Total energy input and energy output of the animal husbandry in the “Beijing Man village” in 2004 (in Gigajoule)

Item	Amount Units per year	Energy GJ per year
Total input energy		32,767
- Industrial energy:		11,033
Electricity	136 MWh	489 *
Pharmaceuticals	6,522 US-$	3,954 *
Coal	100 tons	2,929 *
Repair	4,831 US-$	2,929 *
Transport	1,208 US-$	732 *
- Biological energy:		25,688
Human labor	7,665 man days	97
Feed	1,323 tons	16,690
feeding grass (straws)	365 tons	5,240
Bought sows	6,039 US-$	3,661
Total output energy		11,960
Pork	313 tons	8,113
Milk	146 tons	470
Swine manure	1,250 tons	2,954
Cow manure	216 tons	423

Input energy /output energy: 2.74
Output energy /input energy: 0.37
Output energy /Industrial energy: 1.08
Biological energy /total input energy: 0.47
* Energy demand estimated on the basis of Luo 2001
Money was converted into coal and then into energy (48 US-$ /ton of coal)

4.3 Nutrient value of the agricultural biomass in “Beijing Man Village”

Agricultural biomass like manure and by-products of cropping can be used as fertilizer. The amounts of the nutrients have been calculated in Table 5.

The total nutrition of the crop straw and animal manure comprise 983.19 tons total organic matter (TOM), 25.31 tons total nitrogen after Kjehldahl (TKN), 0.26 tons total available phosphorus (TAP) and 0.15 tons total potassium (TK), respectively. The corn straw and soybean straw were used as roughage for the cows. The other matters were used as fertilizers and returned to the crop land. The amount of TOM, TKN, TAP and TK were equivalent to 5,451.31 kg, 147.41 kg, 1.80 kg and 0.98 kg per hectare.

4.4 Energy input of the subsystem “The People”

In the “Beijing Man village” 1,945 people live in 761 families (census 2004). 80 families have been interviewed about living standards and energy consumption. In 2004, the average income of the 80 evaluated families was 8,350

Table 5:
Calculated nutrients of agricultural biomass in "Beijing Man village" in 2004

Item	Amount /Tons	Moisture %	Content				Amount of nutrition			
			TOM %	TKN %	TAP %	TK %	TOM tons	TKN kg	TAP kg	TK kg
Wheat straws	297	44.1	83	0.65	0.08	1.05	108.71	1,602.32	1.54	2.49
Corn straws	206	68.5	87.1	0.92	0.152	1.18	122.91	1,650.72	2.88	3.69
Soybean straws	186	58.2	89.7	1.81	0.2	1.17	97.10	3,019.84	6.73	4.35
Cow manure	216	75	66.22	1.67	0.43	0.95	107.28	2,388.69	15.51	8.82
Swine manure	1,250	68.7	63.72	2.09	0.9	1.12	547.20	16,646.85	235.13	126.00
Total							983.19	25,308.41	261.79	145.37
Total*							763.18	20,637.85	252.18	137.32
Kg /ha							5450	147.41	1.80	0.98

TOM = total organic matter; TKN = total nitrogen after Kjehldahl; TAP = Total Available Phosphorus; TK=Total Potassium. Total*: Without corn and soybean straws used as the feed.
Source: He 1999

Yuan (1,008 US-$). That is a good income compared to other rural areas in China (see page 2). The average energy consumption was 113 GJ per year and family (Table 6). The coal energy is about 79 % of the total energy consumption of a family. The coal is mostly used for heating in winter (open fire in stoves). Together, electricity, honeycomb-briquette and liquefied petroleum gas (LPG) cover 21 % (3 %, 15 % and 3 %, respectively) of the energy. The cooking energy is mostly supplied by liquefied petroleum gas and honeycomb briquettes.

No data about food consumption could be gathered in the survey. Only questions about the money spent for food were asked. Consumption patterns can be derived from the statistical yearbook (China Rural Statistical Yearbook, 2003). According to the statistics, the annual total food consumption of a person in Beijing rural area is 83.10 kg wheat, 16.20 kg corn, 0.69 kg soybean, 11.10 kg pork and 10.51 kg milk. Table 7 shows the biological energy demand per family is 4.94 GJ per year, which is very low compared to 114 GJ/year for cooking, electricity and heating.

In 2004, the energy value of the food was just 1.94 GJ/person/year, but the energy demand for cooking, electricity and heating was 44.7 GJ/person /year. This is much more than mentioned in the statistics for Beijing (27.4 GJ/person/year). The reason is the low energy efficiency of coal as fuel, but coal and mine stone are produced in the area. Therefore coal has been used as fuel for a long time in "Beijing Man village".

Table 6:
Total energy input of the people who lived in the "Beijing Man village" in 2004 (in Gigajoule)

Item	Average energy consumption per family (n=80; in GJ per year)	Calculated energy consumption for the total village (GJ per year)
Liquefied petroleum gas (LPG)	3.40	2,587
Honeycomb-briquettes	16.87	12,840
Coal	89.88	68,397
Electricity	3.73	2,837
Total energy demand	113.88	86,661

Table 7:
Calculation of the energy of the food which is consumed in "Beijing Man village" in 2004

Food	Food demand* of the village (tons)	Biological energy of the food (GJ/year)	Biological energy of food per family (GJ/year)
Wheat	162	2,543	3.37
Corn	32	521	0.68
Soybean	1	28	0.06
Pork	22	600	0.79
Milk	20	66	0.12
Total		3,758	4.94

* Calculated on the basis of consumption pattern derived from China Rural Statistical Yearbook, 2003

5 Conclusion

"Beijing Man village" system can be described by the energy flow. Plant production, animal husbandry and the people in the village produce and consume energy. In a study carried out in 2004, crop production, animal husbandry and the people of the village of Beijing man were assessed in terms of energy demands and production. Energy can be divided into biological energy (labour, biomass) and industrial energy (fossil fuel, farm inputs, electricity, human needs). The energy flow can be seen in Figure 4.

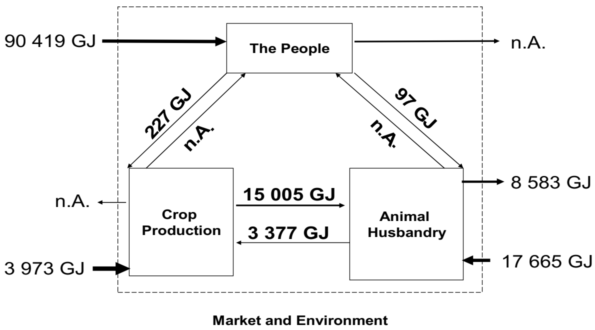

Figure 4:
Model of energy flow in "Beijing Man village" 2004

Table 8:
Total energy input and energy output of "Beijing Man Village" agro-ecosystem in 2004 (in GJ)

Item	Energy (GJ/ha/year)	Energy (GJ per year)
Energy input		**123,211**
- Crop production subsystem		
- Energy input	59.31	9,489
- Industrial energy input	24.83	3,973
- Biological energy input	34.48	5516
- Animal husbandry subsystem		
- Energy input		23,303
- Industrial energy input		11,033
- Biological energy input		12,270
- The people subsystem		
- Energy input		90,419
- Industrial energy input (living energy)		86,661
- Biological energy input(Food)		3,758
Energy output		**31,063**
- Crop production subsystem		
- Energy output	119.39	19,103
- Main product	57.89	9,263
- By-product(straw)	61.5	9,840
- Animal husbandry subsystem		
- Energy output		11,960
- Main product		8,583
- By-product (manure)		3,377

In 2004, the total energy input of the "Beijing Man Village" agro-ecosystem was 123,211 GJ (Table 8). Only 11.5 % of this energy (14,125 GJ) was produced in the system (labour input in farming, seeds, organic fertilizer and feedstuff). The energy output was 31,063 GJ, but 22,950 GJ of this was used in the system (73.9 %). From the whole energy flow, the whole system energy output/input was 0.252. It is very low compared with the other Chinese villages.

From the statistics we know that the average energy consumption per person for heating in rural areas close to Beijing is about 802 kg coal equivalents (1 kg coal equal to 0.0293 GJ = 23.5 GJ/year/person) (REIN 2005). Taken these statistics, about 45,705 GJ of energy are consumed for heating the homes in "Beijing Man village". 2,837 GJ of electricity power is used for light (electricity) and 12,840 GJ cooking fuel and 2,587 GJ liquefied petroleum gas (LPG) for cooking. Together with heating energy, about 63,969 GJ of energy are used for private purposes in the "Beijing Man village". Energy is need for farming as well, e.g. heating and electricity for animal husbandry with 3,417 GJ/year and for farm machines (fuel and oil) of about 74 GJ/year. It is about 2,302 tons coal equivalent. The results from the case study "Beijing Man village" reveal the following three problems:

1. Compared with the energy input, the output of the cropping system is low.
2. There is a high import of nutrients and energy into the system (feed stuff). The manure and the by-products of cropping are not used efficiently.
3. The energy efficiency of fuel (mainly coal for heating) in the households is low.

The model in Figure 5 shows the possibility of integrating biogas production into the system to reduce the energy import and to optimize the production potential as well as the economic output of the system. The biogas production could even be used as a solution for energy for industry if generator technology is available to produce electricity.

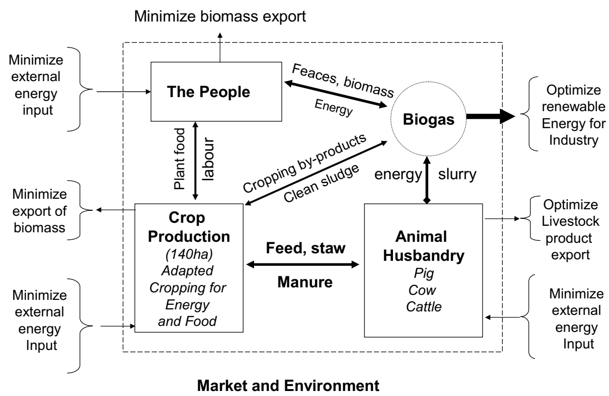

Figure 5:
Model of an optimized system of energy flow with the implementation of biogas production in "Beijing Man village"

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