Assessment of Biomass Resource Availability in China

Chief Editor **LI Jingjing**
BAI Jinming
Ralph Overend

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Assessment of Biomass Resource Availability in China

MOA/DOE Project Expert Team

This book is written and edited based on the output of joint research project "Evaluation of Commercialization of Biomass Energy Conversion Technologies and Their Market Oriented Development Strategy" between Ministry of Agriculture of China and Department of Energy of US. The project has been supported and helped by both governments.

Project Director: WANG Xiwu
Project Manager: BAI Jinming
Senior Consultant: Mm. DENG Keyun
Coordinator: LI Jingming DAI Lin

Chief Directors of Chinese Expert Team:
ZHANG Zhengmin, LI Jingjing, DAI Lin
Energy Research Institute, State Development Planning Commission

Members of Chinese Expert Team:

LU Zengan	Rural Energy Office, Shandong Province
WANG Yaojun	Energy Research Institute, Shandong Province
SUN Li	Energy Research Institute, Shandong Province
LUO Weihong	Rural Energy Office, Zhejiang Province
CAI Changda	Hangzhou Institute of Energy and Environmental Engineering Design
QU Feng	Rural Energy Office, Sichuan Province
JIN Yao	Rural Energy Office, Shanghai
ZENG Banglong	Sanxing Energy and Environmental Engineering Corp. Shanghai
XIONG Chengyong	Chengdu Institute of Biogas Science, MOA
WANG Gehua	Center of Energy & Environmental Protection Technology, MOA
SU Mingshan	Tsinghua University
DONG Wei	Energy Research Institute, Liaoning Province
ZHUANG Xing	Energy Research Institute, State Development Planning Commission
ZHOU Aiming	Energy Research Institute, State Development Planning Commission
SHI Jingli	Energy Research Institute, State Development Planning Commission
LIU Xiaofeng	Energy Research Institute, State Development Planning Commission
SU Zhengming	Energy Research Institute, State Development Planning Commission
HUANG Zhijie	Energy Research Institute, State Development Planning Commission

Expert from US side:
Ralph Overend National Renewable Energy Laboratory, USA

Chief Editor: LI Jingjing, BAI Jinming, Ralph Overend

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Mr. WU Changlun has contributed to the examination and verification of the book. And Mr. ZHOU Aiming has spent many time compiling the manuscript, charts and figures that appeared in the book. A special thanks to them for their work.

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Preface

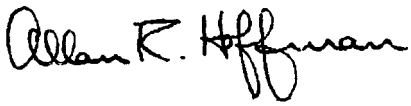
I am Allan Hoffman, Acting Deputy Assistant Secretary for the Office of Utility Technologies of the U.S. Department of Energy (DOE). Recently, I led a DOE team to China to review the progress of bilateral cooperation under the Energy Efficiency and Renewable Energy Protocol signed in 1995. I must tell you how pleased I am to see that China has made considerable progress in the use of renewable energy and attention to environmental issues. I also want to congratulate China's Ministry of Agriculture (MOA) for its efforts to develop rural energy.

The MOA is the implementing agency for Annex I of the Energy Efficiency and Renewable Energy Protocol, which supports The Integrated Rural Energy Construction Program in One Hundred Counties in China. To date, DOE is pleased with joint progress made in three areas: (1) the Gansu Solar Home System project has deployed photovoltaic household systems in 300 homes and 10 schools, with another 300 systems planned by the end of 1998; (2) a comprehensive biomass technology and resource assessment is ready to be published; and (3) a socioeconomic and technology assessment of rural electrification applications is under way.

I applaud that the MOA plans to publish the reports, of which this is the first one in English and Chinese. The publication of those reports represents not only a major milestone in joint activities between the DOE and MOA, but also the foundation for continued U.S.-China cooperation with potential benefits for both countries. China is fortunate to have abundant biomass resources that can be efficiently used as a CO_2-neutral power source, a critical part of China's energy sustainability and pollution prevention efforts.

The DOE would like to gratefully acknowledge the work of the MOA during the development of these publications and anticipates cooperating with the Ministry on future projects. I view our cooperation with China as very important, particularly in renewable energy projects, which can play an important part in China's response to global climate change. This cooperation will also assist China in achieving its Agenda 21 goal of sustainable energy development. Also, the potential market for U.S. renewable energy products and services in China is very large, and joint activities under the Protocol are important entry points for U.S. companies into the

Chinese market. The data in these reports will be useful to the renewables industry and serve to demonstrate the enormous potential of biomass as a sustainable resource.



Allan R. Hoffman
Acting Deputy Assistant Secretary
Office of Utility Technologies
United States Department of Energy

Preface

China, a rapid developing agricultural country, faces the double pressure of economic growth and environmental protection as it enters the 21st century. This period presents an opportunity to transform traditional ways of energy production and consumption and explore and utilize biomass energy and other renewable clean energy resources. Clean energy resources would allow for a sustainable development of the national economy, without sacrificing environmental quality.

According to an old Chinese saying, there are seven things to gather while the door is open: fuel, rice, oil, salt, soy, vinegar, and tea. This means fuel is the primary necessity for a family. At this stage in China's development, exploration and use of biomass energy resources have special and important significance.

First, China has a large population, 70% of which lives in rural areas. The annual rural energy consumption is more than 600 million tons of coal equivalent, and one-third of that amount comes from biomass resources. Second, in China, 65 million people live without electricity; 70 million experience shortages of cooking fuel; and 120 million face the threat of desertification. In addition, inappropriate exploration and utilization of biomass energy has caused ecological deterioration and soil erosion. Third, in areas with rapid economic growth, farmers have transferred their energy consumption to commercial sources such as coal, oil, and electricity, and large amounts of crop straws and stocks are now directly burned in the fields. This has not only caused resource waste and environmental pollution, but has also intensified the demand for conventional energy supplies and has caused social problems. Thus, many believe that the Chinese government should support biomass energy exploration and utilization, as it benefits nature, households, the state, and the world.

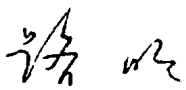
China's Ministry of Agriculture (MOA) and other relevant departments have made biomass energy exploration and utilization a priority. During the 1970s, China implemented many research projects and biomass energy utilization demonstrations. Since the 1980s, R&D to improve biomass energy conversion technologies has been listed in the National Program under key science and technology projects. Some large to medium biogas projects in husbandry farming, biomass gasification systems fed by crop straw, and biomass power generation have shown notable progress.

However, a large gap exists between the current world level and the domestic level of biomass energy exploration and utilization. This is especially true when considering the industrialization of technology and equipment. Issues remain such as how to commercialize biomass energy resource, how to accelerate the industrialization of biomass energy conversion technologies, and how to develop the huge potential market in China. These issues have drawn interest not only from China's government, science and technology, and industrial sectors, but also from the U.S. government and industrial sectors. Collaborative projects between our Ministry and the U.S. Department of Energy (DOE) to explore renewable energy demonstrate the level of interest.

It was my pleasure to meet in Beijing with Dr. Allan Hoffman, Deputy Assistant Secretary, U.S. DOE, and his delegation. We have reached a consensus that rural energy construction will advance the pursuit of sustainable development in coping with conditions in China. As we enter the new century, we will make efforts to improve the rural areas in China and throughout the world.

These three books, prepared collaboratively by MOA's and DOE's team of project experts, are the products of successful cooperation between our agencies on a study of biomass resources and biomass energy conversion technologies. I believe these research results will provide valuable reference information to government, science and technology, and industrial sectors on both sides, and will contribute to the important development of biomass energy technologies in China.

Thanks to all of you, the contributors, for your great effort.



Lu Ming
Deputy-Minister
Ministry of Agriculture, P.R.China

Introduction

Biomass resource, the energy resource for human being since the ancient time, has been playing very important role along with the social development of human being. It is one of the basic elements of natural ecological system in terms of environment view point with no contribution to the global warming during its energy conversion. In China, biomass energy accounts for more than 15% in the mix of energy consumption in recent years.

Chinese government has attached high importance to the development and utilization of biomass energy resource, and conducted long and widely R&D of high and latest biomass energy conversion technology application in the National Program for Key Science and Technology Projects. Meanwhile, Chinese Government has been developing various type of collaboration and activities with foreign governments and international organizations to explore the market of biomass energy resource and its conversion technologies. On February 23, 1995, Ministry of Agriculture of People's Republic of China and Department of Energy of US signed the agreement of "For developing cooperative activities in the area of renewable energy under the hundred counties integrated rural energy development program in China between DOE, US and MOA, P.R. China" as Annex 1 under "The Protocol for Cooperation in the Field of Energy Efficiency and Renewable Energy between The DOE of US and State Science and Technology Commission of P.R. China." In 1996, under this agreement, both sides decided to collaboratively work on the issue of commercialization of biomass energy conversion technologies and their market-oriented development strategy, aimed to identify the commercial potential of advanced technology and its field, design the respectively policy and strategy for investment and market-oriented development, in order to accelerate the development of industrialization and commercialization of biomass energy technologies, through the assessment of biomass resource availability, the analysis on obstacles of technology development, and pilot research and evaluation of typical demonstration project.

The period of this joint project, divided into two phases, is 3 years. Phase 1 is from July, 1996 to July, 1998, Focusing on the availability and logistics of biomass, evaluation of the status quo and developing bioenergy technologies, case studies, and development of a market-oriented development strategy for biomass in China. It is aimed to undertake the pilot research and demonstration projects of bioenergy

technologies for phase 2 based on the output of phase 1.

In order to successfully implement this project, the Energy Research Institute of State Development Planning Commission, and National Renewable Energy Laboratory were nominated as the implementing agencies by MOA of China and DOE of US. The project expert team was established joined with the related specialists from relevant agencies, intuitions, and enterprises to conduct the different tasks in the project.

Based on the joint effort made by the experts from both sides, the work for phase 1 has been initially finished so far. In order to provide the better and efficient service to the national economic construction and society, it has been agreed by both sides to publish the reports with a bilingual text into 3 books titled “Assessment of Biomass Resource Availability in China”, “Biomass Energy Conversion Technologies in China: Development and Assessment”, and “Design for Market-oriented Development Strategy of Bioenergy Technologies”. A CD-ROM would be also attached to each book with the content of the three books. The great support and assistance have been come from Department of Environmental Protection & Energy, and Department of International Cooperation, Ministry of Agriculture, Department of Industry, Ministry of Science and Technology(ex-State Science and Technology Commission) , Energy Research Institute, State Development Planning Commission, the provincial and local rural energy offices, and Department of Energy, US and National Renewable Energy Laboratory along with the project implementation. Here we would like to thank Mr. Wang Xiwu, Mr. Zhang Guozheng, Mr. Li Baoshan, Mr. Hu Yanan, Mr. Gao Shangbin, Mr. Zhou Fengqi, and Mr. Li Junfeng from Chinese side, and Mme. Lee Gerbert, Mr. William Wallace, and Ms. Christie Johnson for their great help.

CHAPTER 1 Study on the Availability of Straw and Stalk Resource in China

1.1 Introduction

Over China's vast land, there are lots of agricultural residues. According to 1995 statistics, the straw and stalk output in China reached about 604 million tons. Calculated with a collection rate of 85%, the available amount of straw and stalk is 513.4 million tons, equal to 205 million tons of carbon equivalent (tce). Much of the 513.4 million tons of straw and stalk are presently used for cooking and heating in rural households. Other uses include forage, industrial raw material for paper production, and organic fertilizer. Presently, most of it is used at low efficiency. For example, in domestic cooking stoves the conversion efficiency is only 10% to 20%. The remainder of the straw is either dumped or burned in the field.

With the rapid development of China's rural economy, and with farmers' increasing incomes, use of commercial energy for rural residential purposes is also rapidly increasing. A combination of increasing incomes and the availability of commercial energy sources, such as liquefied petroleum gas, coal, and even electricity, is rapidly reducing straw consumption. The straw and stalk once used in the traditional way will be displaced, increasing the share of straw and stalk left in field or burned directly. Already, the residual straw and stalk amounts in some regions are more than 60% of the production, which not only damages the environment, but also wastes resources.

The biomass energy resources in China include the residue from agriculture and forestry processing, covering solid residue, the concentrated organic waste water from the agriculture products processing, crop straw and stalk burned as fuel, fuelwood, and human and animal excreta, and urban residential refuse as well. Although China is in transition from a rural and agricultural society to an urban and industrial society, the rural population is still 80% of the total national population. Straw and stalks are widely distributed and available in all of the regions.

1.2 Crop And Crop Residues: Historical Trends in Availability

1.2.1 The historical situation of land use

It is very necessary to know the changing trend of the land utilization to present the straw and stalk resource available in China. In describing the crop straw and stalk

resource availability in China, the first index is the changing trend of the cultivated land area. Because of capital construction of roads, housing and industries from 1980 to 1995, the arable land area decreased, on average, by 410,000 hectares (ha) per year from 1980 to 1985; 711,000 ha per year from 1986 to 1990; and 657,000 ha per year from 1991 to 1995. Table 1.1 shows the land area change in China during this time.

The change in cultivated land area will directly affect the sown crop area. According to Table 1.2, the sown area of rice has decreased year by year, while that of wheat, corn, and cotton has been stable. The sown area of soybeans, tubers, oil bearing crops, and sugarcane has increased slightly. In general, the area sown to grain will continue to decrease. For example, grain area was 80% in 1980; 77% in 1986; 76% in 1990; and 73% in 1995.

Table 1.1 Cultivated land area in China from 1980 to 1995 (1,000 ha)

Year	Actual cultivated area at year end			Annual decrease in land area
	Total	Irrigated land	Dry land	
1980	99,305.2	25,322.2	73,983.0	940.8
1985	96,846.3	25,033.0	71,813.3	1,597.9
1986	96,229.9	5,055.1	71,174.7	1,108.3
1987	95,888.7	25,104.1	70,784.5	817.5
1988	95,721.8	25,077.7	70,644.1	644.7
1989	95,656.0	25,265.8	70,390.2	517.5
1990	95,673.0	25,518.9	70,154.1	467.4
1991	95,653.6	25,706.5	69,947.1	488.0
1992	95,425.8	25,597.2	69,828.6	738.7
1993	95,101.4	25,028.0	70,073.4	732.3
1994	94,906.7	24,762.9	70,143.8	708.7
1995	94,970.9	24,850.5	70,120.4	621.1

Source: *China Statistical Yearbook 1996*

Table 1.2 Crop area plantings in China (1,000 ha)

Year	Rice	Wheat	Corn	Soybeans	Tubers	Oil bearing	Cotton	Sugarcane
1980	33,879	29,228	20,353	-	10,153	7,928	4,920	479
1985	32,070	29,218	17,694	-	8,572	11,800	5,141	965
1986	32,266	29,616	19,124	-	8,685	14,414	4,306	950
1987	32,193	28,798	20,212	-	8,867	11,180	4,844	859
1988	31,987	28,785	19,692	-	9,054	10,619	5,535	924
1989	32,700	29,841	20,353	-	9,097	10,504	5,203	959
1990	33,064	30,753	21,401	-	9,121	10,900	5,588	1,009
1991	32,590	30,948	21,574	9,163	9,078	11,530	6,538	1,164
1992	32,090	30,496	21,044	8,983	9,057	11,489	6,835	1,246
1993	30,355	30,235	20,694	12,377	9,220	11,142	4,985	1,088
1994	30,171	28,981	21,152	12,736	9,270	12,081	5,528	1,057
1995	30,744	28,860	22,776	11,232	9,519	13,101	5,422	1,125

Source: *China Statistical Yearbook, 1996*

1.2.2 Historical main crop yields

According to Table 1.3 and Figure 1.1, from 1980 to 1995, the output of rice and sugarcane fluctuated, while the output of wheat, oil bearing crops, corn, tubers, and cotton increased.

Table 1.3 Main crop production from 1980 to 1995 (million tons)

Year	Rice	Wheat	Corn	Soybeans	Tubers	Oil bearing	Cotton	Sugarcane
1980	139.91	55.21	62.60	-	28.73	7.69	2.71	22.81
1985	168.57	85.81	63.83	-	26.04	15.78	4.15	51.55
1986	172.22	90.04	70.86	-	25.34	14.74	3.54	50.22
1987	174.26	85.90	79.24	-	28.20	15.28	4.25	47.36
1988	169.11	85.43	77.35	-	26.97	13.20	4.15	49.06
1989	180.13	90.81	78.93	-	27.30	12.95	3.79	48.80
1990	189.33	98.23	96.82	-	27.43	16.13	4.51	57.62
1991	183.81	95.95	98.77	12.47	27.16	16.38	5.68	67.90
1992	186.22	101.59	95.38	12.52	28.44	16.41	4.51	73.01
1993	177.51	106.39	102.70	19.50	31.81	18.04	3.74	64.19
1994	175.93	99.30	99.28	20.96	30.25	19.90	4.34	60.93
1995	185.23	102.21	111.99	17.88	32.63	22.50	4.77	65.42

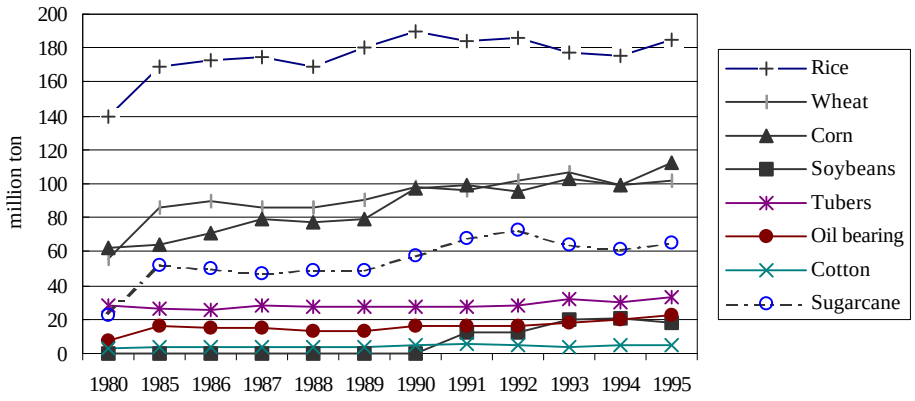


Figure 1.1 Trends in the production of major crop output
Source: *China Statistical Yearbook, 1996*

1.3 The State-of-the-Art of Crop Production in all of China's Regions

1.3.1 Regional land use

Table 1.4 shows the ratio of irrigated land area to dry land area is about 1:1 in

central China, east China, and southwest China. In these regions, irrigated land area accounts for about 44% of the cultivated area; dry land accounts for about 56% of the cultivated area. However, there is much less irrigation in northeast China, north China, and northwest China. Here, the farming is mainly on dry land, which accounts for more than 80% of the actual cultivated land area.

Table 1.4 Tillage areas in China by region in 1995 (1,000 ha)

Region	Actual tillage areas at year end			Annual decreased amount
	Total	Irrigated land	Dry land	
Beijing	399.5	23.7	375.8	2.9
Tianjin	426.1	48.5	377.7	1.5
Hebei	6,517.1	126.5	6,390.7	19.4
Shanxi	3,645.1	8.8	3,636.3	15.4
Inner Mongolia	5,491.4	84.3	5,407.1	77.5
Liaoning	3,389.7	468.6	2,921.1	27.0
Jilin	3,953.2	425.2	3,528.0	19.5
Heilongjiang	8,995.3	868.8	8,126.5	23.4
Shanghai	290.0	253.9	36.1	4.8
Jiangsu	4,448.3	2,669.7	1,778.6	23.7
Zhejiang	1,617.8	1,344.9	272.9	22.2
Anhui	4,291.1	1,857.6	2,433.5	13.5
Fujian	1,204.0	972.5	231.5	9.5
Jiangxi	2,308.4	1,946.9	361.6	8.0
Shandong	6,696.0	156.7	6,539.3	34.4
Henan	6,805.8	446.6	6,359.2	31.0
Hubei	3,358.0	1,780.4	1,577.6	21.4
Hunan	3,249.7	2,562.9	686.8	18.3
Guangdong	2,317.3	1,698.7	618.7	35.2
Guangxi	2,614.2	1,540.3	1,073.9	29.0
Hainan	429.2	248.2	181.0	3.9
Sichuan	6,189.6	3,156.0	3,033.6	32.8
Guizhou	1,840.0	768.4	1,071.6	7.0
Yunnan	2,870.6	958.8	1,911.9	35.5
Tibet	222.1	0.8	221.3	0.4
Shaanxi	3,393.4	176.0	3,217.4	54.0
Gansu	3,482.5	9.3	3,473.2	3.5
Qinghai	589.9		589.9	1.2
Ningxia	807.2	170.9	636.3	3.8
Xinjiang	3,128.3	76.7	3,051.6	41.6

Source: *China Statistical Yearbook, 1996*

Based on the geographical distribution, temperature conditions, and water availability, southern China has land suitable for growing rice, sugarcane, and oil

bearing crops. In northern China, the seasonal temperature changes support the growth of corn, soybeans, and tubers; therefore the areas sown to these crops are greater than other regions. However, wheat is planted across the country, and the largest cotton growing areas are southeast China and central China. Cotton is planted mainly in east China and central China, with some in north China and northwest China. From an analysis of cropland use in each region as shown in Table 1.5, the crops and regions are ranked in Table 1.6.

Table 1.5 1995 crop areas in China by province (1,000 ha)

Region	Rice	Wheat	Corn	Soybeans	Tubers	Oil Bearing	Cotton	Sugarcane
Beijing	23.3	172.2	207.8	17.2	5.5	11.8	3.3	-
Tianjin	48.1	141.2	158.6	58.2	3.4	22.6	17.2	-
Hebei	128.7	2,500.7	2,290.8	655.4	407.0	604.5	700.6	-
Shanxi	6.4	917.0	768.2	414.9	311.5	342.4	127.1	-
Inner Mongolia	78.6	1,016.7	992.1	778.7	355.3	556.8	-	-
Liaoning	472.6	171.3	1517.5	300.5	102.5	131.8	31.0	-
Jilin	429.6	80.4	2344.1	435.9	89.7	151.1	-	-
Heilongjiang	835.1	1,116.3	2411.2	2,589.0	235.3	147.3	-	-
Shanghai	210.0	61.1	8.1	10.7	1.4	79.4	3.3	1.1
Jiangsu	2,250.3	2,150.4	462.0	351.0	166.7	687.4	564.9	4.0
Zhejiang	2,137.8	208.2	39.3	144.4	159.6	309.3	64.5	11.8
Anhui	2,156.1	1,992.7	552.4	517.7	528.4	1,263.5	443.2	4.8
Fujian	1,406.3	69.1	29.6	130.7	347.3	118.2	-	37.5
Jiangxi	3,014.9	60.0	41.1	234.6	143.5	1,057.0	131.8	40.2
Shandong	121.1	4,010.9	2,694.8	535.5	596.7	879.8	666.3	-
Henan	450.5	4,814.0	1,957.5	678.0	698.7	1,271.5	1,000.1	5.0
Hubei	2,408.6	1,179.9	393.8	327.9	397.7	1,047.0	502.0	16.0
Hunan	4,084.0	168.7	137.9	284.5	373.6	890.7	185.3	29.0
Guangdong	2,699.8	26.5	65.5	123.4	519.2	347.4	-	230.2
Guangxi	2,420.7	21.6	550.1	321.3	312.6	284.1	1.8	454.3
Hainan	393.6	-	17.1	15.6	143.5	51.2	-	72.5
Sichuan	3,003.3	2,332.0	1,715.8	569.2	1,995.0	1,048.9	140.7	35.6
Guizhou	741.0	562.0	646.7	289.5	532.9	446.2	2.6	8.5
Yunnan	941.0	625.0	988.0	498.0	307.0	145.4	2.0	174.9
Tibet	1.0	51.9	2.8	18.6	1.3	18.5	-	6.9
Shaanxi	139.3	1,600.2	902.6	372.5	370.4	302.2	72.8	0.2
Gansu	6.8	1,357.3	346.2	340.7	313.3	328.2	18.0	-
Qinghai	-	206.0	-	63.5	37.7	149.8	-	-
Ningxia	62.1	294.3	95.0	90.4	52.9	100.9	0.3	-
Xinjiang	73.38	952.6	439.2	64.7	9.2	306.7	742.9	-

Source: *China Statistical Yearbook, 1996*

Table 1.6 Ranking of crop areas in China by region

Region	Rice	Wheat	Corn	Soybeans	Tubers	Oil bearing	Cotton	Sugarcane
North China	5	3	2	5	4	4	4	5
Northeastern China	4	6	1	1	6	6	6	6
East China	2	1	3	2	1	1	2	3
Mid-China	1	2	4	3	3	2	1	1
Southwestern China	3	5	5	4	2	3	5	2
Northwestern China	6	4	6	6	5	5	3	4

1.3.2 Analysis of crop outputs of each region in China

Figure 1.2 shows the production share of each crop in China for 1995. Rice, with a 34.1% share, is the largest crop. It grows in all regions except the Qinghai Province. Even in Tibet, there is a 5,000-ton rice harvest. Corn is second in importance with a share of about 20.6%. The main corn producing areas lie in the North Yellow River and along the Yellow River. Corn is used as a raw material for brewing and as feed for livestock.

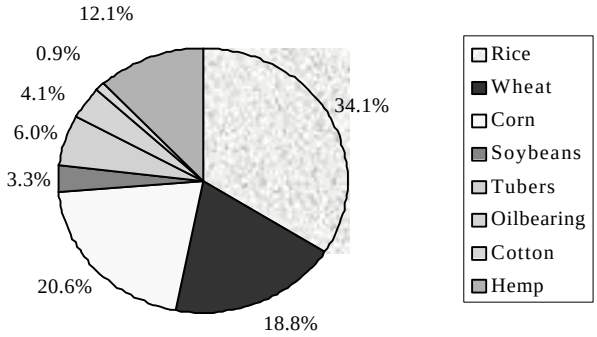


Figure 1.2 Ratio of crops in China by type

Wheat output ranks third at about 18.8%. It grows in 30 provinces, cities, and autonomous regions except for Hainan. Wheat production is relatively minor in the Jiangxi, and Guangdong provinces and the Guangxi Autonomous Region. Soybeans, with an output share of about 3.3%, are not planted to any great extent the major city regions such as Shanghai and Beijing. In Hainan, Tibet, and Ningxia, the climate is unsuitable for soybean production. Tubers, with a about a 6% share of production grow in the provinces and autonomous regions along the Yangtze River. Oil bearing crops, with a 4.1% share, are geographically distributed in the same regions as soybeans. Cotton, an economic crop, grows mainly in the areas between the Yellow River and the Yangtze River. Cotton output in other areas is rather small except for Xinjiang. Sugarcane output is very regional, and is centralized in the South China. Table 1.7 lists crop production in each region.

Table 1.7 Crop product outputs by region in 1995 (1,000 tons)

	Rice	Wheat	Corn	Soybeans	tubers	Oil bearing	Cotton	Sugarcane
Beijing	168	1,004	1,330	41	29	33	3	-
Tianjin	389	654	805	101	18	40	11	-
Hebei	903	10,603	11,834	943	1,377	1,099	370	-
Shanxi	42	2,701	4,035	367	642	223	91	-
Inner Mongolia	396	2,622	5,184	670	743	702	-	-
Liaoning	2,618	633	8,247	442	363	198	24	-
Jilin	2,969	191	14,785	897	348	256	-	-
Heilongjiang	4,699	2,710	12,126	4,368	815	201	-	-
Shanghai	1,586	238	46	34	7	158	4	49
Jiangsu	17,986	8,926	2,708	882	902	1,595	562	228
Zhejiang	12,188	541	142	299	708	500	62	658
Anhui	12,699	6,991	2,719	721	2,353	1,918	301	178
Fujian	7249	186	69	214	1,398	233	-	2,486
Jiangxi	14865	75	89	369	623	1,036	119	2,000
Shandong	912	20,607	15,430	1,273	3,576	3,150	471	-
Henan	2,958	17,542	9,578	1,212	2,860	2,980	770	207
Hubei	17,307	3,636	1,501	646	1,352	1,894	586	736
Hunan	24,384	271	389	473	1,271	1,120	224	1,415
Guangdong	14,716	69	219	201	2,066	710	-	15,916
Guangxi	12,600	28	1,552	362	506	453	1	25,557
Hainan	1,609	-	37	17	346	76		3,359
Sichuan	20,979	7,309	6,296	1,253	6,617	1,702	112	1,795
Guizhou	4,252	1,078	2,385	307	1,346	588	1	269
Yunnan	5,119	1,375	3,393	772	789	196	1	10,559
Tibet	5	249	11	46	3	34	-	-
Shaanxi	642	4,104	2,823	306	689	382	40	4
Gansu	53	2,542	1,259	343	597	317	23	-
Qinghai	-	695		132	148	162	-	-
Ningxia	462	689	608	55	89	56	-	-
Xinjiang	472.4	3,939	2,387	128	46	494	994	-

Table 1.8 Top ten counties by grain production

No.	Province	County	Total grain production (ton)	Sown area (ha)	Sown density (kg/*mu*)
1	Jilin	Nongan	2,024,061	266,528	506
2	Jilin	Yushu	2,010,117	255,236	525
3	Jilin	Gongzhuling	1,830,140	206,147	592
4	Jilin	Lishu	1,675,500	180,085	620
5	Heilongjiang	Shuangchen	1,410,000	178,589	526
6	Liaoning	Changtu	1,359,286	199,593	454
7	Jilin	Dehui	1,181,872	193,803	407
8	Hubei	Xiangyan	1,164,905	138,630	560
9	Heilongjiang	Zhaodong	1,151,035	178,200	431
10	Heilongjiang	Hailun	1,134,683	219,526	345

Table 1.9 Distribution of the ten counties

Province	Number of counties	Order by grain production
Jilin	5	1,2,3,4,7
Heilongjiang	3	5,9,10
Liaonin	1	6
Hubei	1	8

Table 1.10 Distribution of the 18 counties over million tons Grain production

Province	Number of Counties
Heilongjiang	6
Jilin	6
Liaonin	1
Hubei	3
Shangdong	1
Jiangsu	1
Total	18

1.3.3 Calculation of crop straw and stalk production in China

Crop straw and stalk outputs are calculated based on crop outputs and the ratio of grain production to stalk mass. Table 1.11 lists these outputs and their energy contents. This shows that China's total crop straw and stalk production in 1995 was 600 million tons, with an energy content equal to 300 million tce.

Table 1.11 Main crop straw and stalk outputs in 1995

Crop	Output (1,000 tons)	Ratio of grain to grass	Straw and stalk (1,000 tons)	Coefficient equal to tce	Standard coal (1,000 tce)
Rice	185,230.0	1:0.623	115,398.3	0.429	49,505.9
Wheat	102,210.0	1:1.366	139,618.9	0.50	69,809.5
Corn	111,990.0	1:2.0	223,980.0	0.529	118,485.4
Other miscellaneous	16,690.0	1:1	166,690.0	0.05	8,345.0
Soybeans	17,875.0	1:1.5	26,812.5	0.543	14,559.2
Tubers	36,220.0	1:0.5	16,310.0	0.486	7,926.7
Oil bearing	22,503.3	1:2.0	45,006.0	0.529	23,808.2
Cotton	4,768.0	1:3.0	14,304.0	0.543	7,767.1
Sugarcane	65,417.0	1:0.1(leaf)	6,541.7	0.441	2,884.9
Total			604,661.4		303,091.9

1.4 Main Utilization of Straws and Stalks in China

According the calculations in Table 1.11, China produced about 604 million tons of straw and stalk in 1995. About 15% of that amount was returned to the field as fertilizer and left in the field, leaving 513.4 million tons for other uses. Currently, these crops have three uses: as industrial material, mostly for papermaking, representing 2.3% of the total available straw and stalk; as forage, representing about 24% of the total available straw and stalk; and as fuel, representing 58.7%, or 355.09

million tons, of the total available straw and stalk. However, the best estimate suggests that consumption as fuel is about 73 million tce, or about 150 million tons (*Special Issues: Report of Sustainable Development Strategy Study in Rural Area*, Energy Consulting Programme of Chinese Science Academy of Engineering).

1.4.1 Analysis of the potential use of straw and stalk in pulp and paper production

1.4.1.1 Introduction to China's paper making industry

Paper and board output increased significantly during the "Eighth Five-Year Plan" (1991-1995). The output in 1995 was 14.40 million tons more than in 1990, when it was 13.72 million tons. During this time, the average annual growth rate of production was 15.4% per year, or 2.88 million tons. This rate was much higher than in the rest of the world. Table 1.12 summarizes the growth rate of paper and board production.

Table 1.12 Output and growth rate of paper and board in China from 1990 to 1995

Year	Total output (million tons)	Growth compared to previous year (million tons)	Growth compared to previous year (%)	Worldwide growth rate compared to previous year (%)
1990	13.719	0.385	2.9	2.1
1991	14.987	1.069	7.8	0.8
1992	17.251	2.464	16.7	2.4
1993	18.200	1.949	11.3	2.1
1994	21.383	3.183	17.5	6.7
1995	28.123	6.740	37.5	3.5

Source: *Chinese Paper Making Yearbook 1996*

By 1995, there were about 10,000 paper mills in China (not including hand manufacturing). The total production of paper and board was 28.12 million tons (operating at about 88% of total capacity). The average production among the 10,000 paper mills is 3,200 tons, even though there are many small mills and only a few large mills. Among the independent paper mills, only one has an annual product capacity greater than 200,000 tons, and about 10 mills have capacities exceeding 100,000 tons. Through mill investments and capacity increases in recent years, about 100 factories now have capacities greater than 30,000 tons. In the main paper producing countries, the average annual production is 180,000 tons, and the average around the world is 50,000 tons.

During the Eighth Five-Year Plan, paper and board output increased rapidly in the main areas of wheat production or where recycling was possible. These areas include Henan, Shandong, Hebei, Jiangsu, Sichuan, and Anhui. Growth was most rapid in Fujian, Guangxi, Heilongjiang, Liaoning, and Hunan, where wood fiber and reeds are the raw materials.

Water pollution from the papermaking industry has been very severe especially in small cities and towns. While large and medium paper mills meet the emission standards, small paper mills have no water treatment capabilities. Thus, small paper mills discharge large amounts of untreated waste water from small paper mills into nearby rivers. In response to public concern about water pollution, the State Council developed a plan to improve the situation on the Huaihe River. The plan was to close small paper mills in the provinces of Henan, Shandong, Jiangsu and, Anhui with annual production capacities less than 5,000 tons by early 1997. Slightly larger mills have been encouraged to either close or expand while investing in waste treatment technologies to meet the waste water emission standards.

1.4.1.2 Distribution of pulp, paper, and board production in China

Table 1.13 lists machine made pulp production by region from 1985 to 1995. In order of highest to lowest output, the regions include central China, east China, north China, northeast China, southwest China, and northwest China.

Table 1.13 Machine made pulp production in China by region excluding rough pulp (million tons)

Year	Nationwide	North China	Northeast China	East China	Central China	Southwest China	Northwest China
1985	6.1530	0.7133	1.1971	1.5816	1.7755	0.6589	0.2268
1986	6.7915	0.8207	1.2657	1.8167	1.9356	0.6581	0.2945
1987	5.2043	0.5804	1.2246	1.5771	1.1639	0.4571	0.2012
1988	8.7257	1.0929	1.4777	2.4000	2.5367	0.8524	0.3664
1989	8.6856	1.0514	1.4421	2.4040	2.5775	0.8712	0.3394
1990	8.3496	1.0801	1.3857	2.3225	2.3183	0.8427	0.4003
1991	8.6059	1.1177	1.3295	2.3749	2.4230	0.9084	0.4524
1992	10.3181	1.3891	1.3313	2.5722	3.6313	0.9344	0.4598
1993	9.2328	0.9733	1.1772	2.4880	3.1860	0.7429	0.6654
1994	10.0669	0.8268	1.1882	2.4854	3.6203	1.2483	0.6980
1995	11.4369	1.7764	1.4059	2.3393	3.9082	1.0678	0.9506

Source: *Chinese Paper Making Yearbook 1996*

1.4.1.3 The supply of fibrous raw material for pulp and paper making in China

Plant fiber is the basic raw material in the pulp and paper making industry. Throughout the world, wood is the primary source of pulp and paper fiber, accounting for about 90% of all fiber. In China, annual plants are the major sources of fiber, and only about 25% comes from wood. Table 1.14 shows the sources of fiber in China.

Table 1.14 Consumption of fibrous raw materials for pulp and paper making in China

Fiber source	Unit	1991	1992	1993	1994	1995
Pulp	million tons	8.6059	10.318	9.2328	10.0669	11.4369
Total (not including waste paper)	%	100	100	100	100	100
Wood	%	25.6	26.1	26.2	27	26.8
Reed	%	13.5	13.1	11.2	12.9	13.7
Bagasse	%	4.6	4.3	4.3	2.4	2.4
Bamboo	%	2.3	2.5	2.0	2.3	2.3
Straw and stalk	%	44.4	44.7	48.5	48.4	48.5
Waste hemp and clothing	%	5.1	4.9	4.2	3.8	3.2
Other	%	4.5	4.7	3.2	3.2	3.1

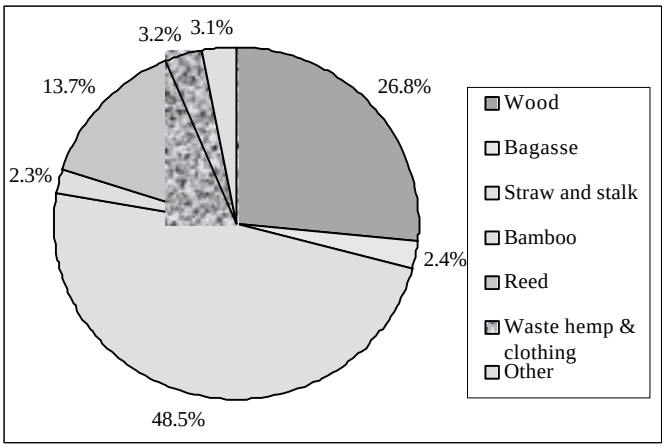


Figure 1.3 Machine made pulp fiber sources in 1995

Source: *Chinese Paper Making Yearbook 1996*

Table 1.15 shows the proportion of wood consumption in recent years has been (including waste paper) constant at 26-27% in recent years, while the grass consumption increased from 44.4% in 1991 to 48.5% in 1995. The enterprises using these raw materials developed rapidly in provinces such as Henan, Hebei, Shandong, Jiangsu, Anhui and Sichuan. Statistics show these regions are rich in straws and stalks.

Table 1.15 Pulp output and percentage in 1995

Pulp type	Consumption (million tons)	Percent of total consumption
Wood	3.088	26.8
Reed	1.602	13.9
Bagasse	0.286	2.4
Bamboo	0.263	2.3
Straw and stalk	5.547	48.1
Waste hemp and cotton	0.389	3.2
Others	0.354	3.1

Table 1.16 Consumption of pulp raw material

Pulp Type	Consumption (million tons)
Wood	10.248
Reed	4.005
Bagasse	0.715
Bamboo	0.655
Straw and grass	13.868
Waste hemp and cotton	0.584
Others	0.460
Total	30.535

Source: *Chinese Paper Making Yearbook 1996*

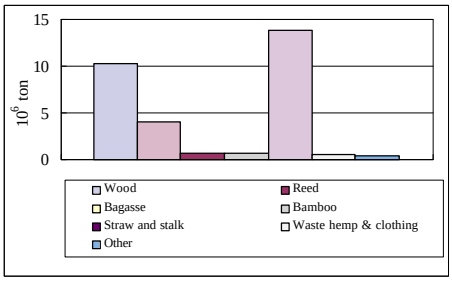


Figure 1.4 Consumption of pulp raw material in 1995

1.4.1.4 Projections for the pulp and paper industry for the Eighth Five-Year Plan and in 2010

China's average per capita consumption of paper and board is very low, ranking it sixty-third in the world. China International Consultant Corporation projects the average annual growth rate of paper consumption will be 9% in the Ninth Five-Year Plan, and could reach 34.25 million tons in 2000.

According to the Chinese Paper Making Association, by 2000, paper and board production in China will be 30 million tons, with an annual pulp consumption of 25.11 million tons. Wood pulp will increase from 13% today to 18% in 2000, while average per capita consumption will increase from 23.4 kg (kilograms) to 26 kg. The average pulp consumption per ton of paper and board will be 840 kg. Table 1.17 shows pulp fiber consumption forecasts for 2000.

Table 1.17 Forecast pulp output and consumption in 2000

Pulp type	Pulp consumption (million tons)	Percent of total consumption
Wood:	4.52	22.5
Reed	1.26	6.3
Bagasse	0.92	4.6
Bamboo	0.47	2.3
Straw and stalk	8.40	41.8
Waste hemp and cotton	1.00	5.0
Waste paper	3.04	15.1
Others	0.50	2.5
Total	20.11	

Table 1.18 Consumption of pulp raw material in 2000

Pulp type	Consumption (million tons)
Wood	15.00
Reed	3.15
Bagasse	2.30
Bamboo	1.17
Straw and grass	21.00
Waste hemp and cotton	1.50
Waste paper	9.95
Others	0.65
Total	54.72

Note: China's waste recycling rate is 30% and wood consumption is 1 million m^3.

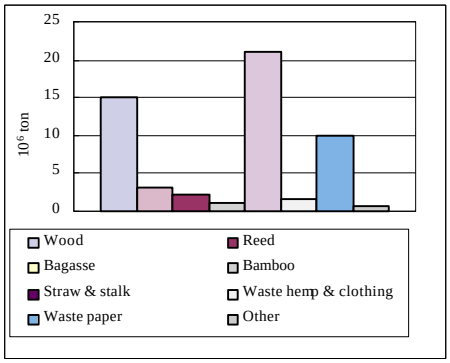


Figure 1.5 Consumption of pulp raw material in 2000

In 2010, the total paper and board output will be 40 million tons, which will consume 36.80 million tons of pulp. The proportion of wood pulp proportion is estimated at 22%. A reduction in the proportion of grass pulp to 28% will decrease the demand of straw and stalk to 28 million tons.

1.4.2 Analysis of straw and stalk resource consumed as forage

The structure of animal husbandry has been influenced strongly by the natural forage resources available, which include crop straws and stalks, grasslands, and intertidal zones. The population of large animals at the end of 1995 was 158.62 million. Most of the horse, donkey, and mule populations are raised in the central grassland and mountainous areas. In winter, they are maintained on hay and grain.

There are significant differences between raising cattle and the animals described above. Based on characteristics of livestock type, forage consumption, and production system, China's land can be divided into pasturage, and farming areas. Pastures include a large range of grassland and the wide grassland, or gobi. The farming area includes arable crops and a small range of grassland. It is a more intensive production system.

A wide boundary separates pasture and farming areas. It begins east of the Daxinganling Mountain in Heilongjiang Province with the Liaohe River at the bottom, along with the Yinshan Mountains and Erdols in Inner Mongolia (not including the Houtao Plain). The boundary extends to the Qilian Mountains (except the River West Passage) in Gansu Province, ending at the Qingzang Plateau (Source: Francis Tuan, Division of China, U. S. Department of Agriculture). Defined this way, southeast China, comprises 54% of China's land area and is primarily the agricultural zone.

The remainder is pastureland. Gansu, Ningxia, Inner Mongolia, Xinjiang, Qinghai, and Tibet are part of the pasturelands, and the other 24 provinces and municipal cities fall into the agricultural area. Figure 1.6 illustrates the boundaries.

Figure 1.6 Geographic distribution of pasturing area in China

In Gansu, Ningxia, Inner Mongolia, Xinjiang, Qinghai, and Tibet, both milk and beef cattle feed on forage fodder. In the agricultural area, especially in suburban milk and beef cattle farms, the animals are confined and eat pulverized straw and stalk delivered as forage. They also eat grass and concentrated feeds. Whether on the grassland ranges or in feedlots, the animals are dependent on the same forage sources such as forage grasses and /or straw and stalk, so the natural rule of "Satiety in Summer, Fat in Autumn, Thin in Winter" still holds.

In 1995, 132.06 million cattle (including 4.174 million milk cattle) were raised in China. Of those, 21.94 million lived on the grassland ranges of Gansu, Ningxia, Qinghai, Inner Mongolia, Xinjiang, and Tibet. The 110.11 million cattle in the agricultural area live mainly on straws and stalks. The daily intake of grass or straw and stalk is 7.5 kilograms (kg) ("Food Development Strategy in Mid- and Long-Term in China," Chinese Academy of Agricultural Science, 1993). To assure an adequate diet in winter, the cattle also require a supplement of 0.5-1.0 kg/day of feed concentrate, which amounts to 60 kg in one winter. Draft cattle also require additional feed concentrate, calculated 120 kg for a two-month working period.

Farmers store straw and stalks from the harvest season for winter and spring use. In

cities and towns, the forage must be transported from areas which are rich in straw and stalk. Based on a study and field investigation by the Animal Husbandry Institution of Academy of Agriculture Science of China, the recommended daily consumption of straw and stalk for farm cows is 3.49 kg.* (without consideration of regional differences and with consideration of ammoniation).

Assuming an annual consumption of 365 × 3.49 = 1,274 kg of straw and stalk, the cattle population of China will consume 140 million tons, representing 23% of the total straw and stalk in China. Table 1.19 illustrates the number of farm cattle raised in each region in 1995 and their average straw and stalk consumption.

Table 1.19 Farm cattle population by region and average straw and stalk consumption in 1995

Region	Number of cattle (million head)	Straw and stalk consumption (million tons)	Region	Number of cattle (million head)	Straw and stalk consumption (million tons)
Beijing	0.141	0.1796	Jiangxi	3.844	4.8967
Tianjin	0.222	0.2828	Shandong	12.393	15.7868
Hebei	5.793	7.3794	Henan	12.536	15.969
Shanxi	2.517	3.2063	Hubei	4.095	5.2164
Liaonin	3.016	3.8419	Hunan	4.305	5.4839
Jilin	3.843	4.8954	Guangdong	4.715	6.0062
Heilongjiang	5.115	6.5157	Guangxi	7.971	10.1539
Shanghai	0.069	0.0879	Hainan	1.465	1.8662
Jiangshu	0.991	1.2624	Sichuan	11.159	14.2149
Zhejiang	0.503	0.6407	Guizhou	6.493	8.2711
Anhui	7.013	8.9335	Yunnan	7.861	10.0137
Fujian	1.276	1.6254	Shaanxi	2.781	3.5426
Ningxia	3.703	4.7170	Total	113.820	144.9900

Source: *Chinese Statistical Yearbook 1996*

Analysis of Table 1.19 provides the total straw and stalk resource available by region in 1995, as shown in Table 1.20. Except for the resources used as forage and raw material for paper making, the potential straw and stalk resource as energy can also be estimated.

Table 1.21 lists the ten provinces, from Table 1.20, with the highest straw and stalk resource availability in 1995. The resource base in these ten provinces represents more than 70% of the national resource availability. Therefore, these should be the focus of future straw and stalk resource development in the future.

* A cattle in the farm area consumes 3.49 kg stalk every day, recommended by the Chinese Academy of Agricultural Science.

Table 1.20 Distribution and availability of straw and stalk in 1995 (million tons)

		Total straw and stalk outputs	Fertilizer and collection loss	As forage	As raw material of paper	As energy
National		604.664	90.700	144.990	13.879	355.094
East China	Shandong	71.544	10.732	15.787	0.715	44.310
	Jiangsu	36.043	5.406	1.262	0.391	28.984
	Anhui	30.470	4.571	8.934	0.303	16.663
	Zhejiang	11.227	1.684	0.641	0.336	8.566
	Jiangxi	13.592	2.039	4.897	0.350	6.306
	Fujian	7.199	1.080	1.625	0.723	3.771
	Shanghai	2.349	0.352	0.088	0.018	1.891
South China	Henan	57.056	8.558	15.969	2.496	30.034
	Hubei	26.572	3.986	5.216	0.46	16.910
	Hunan	21.294	3.194	5.484	0.752	11.864
	Guangdong	14.603	2.190	6.006	0.782	5.625
	Guangxi	15.809	2.371	10.154	0.239	3.045
	Hainan	2.319	0.348	1.866	0.010	0.095
Northeast China	Heilongjiang	38.799	5.820	6.516	0.468	25.996
	Jilin	34.268	5.140	4.895	0.613	23.620
	Liaoning	20.859	3.129	3.842	0.623	13.264
North China	Hebei	44.682	6.702	7.379	1.185	29.415
	Inner Mongolia*	17.533	2.630	-	0.153	14.890
	Shanxi	13.933	2.090	3.206	0.704	7.932
	Beijing	4.843	0.726	0.180	0.010	3.928
	Tianjin	3.576	0.536	0.283	0.101	2.656
Southwest China	Sichuan	45.310	6.797	14.215	1.069	23.230
	Yunnan	15.413	2.312	10.014	0.176	2.912
	Guizhou	11.787	1.768	8.271	0.050	1.699
	Tibet*	1.06	0.159	-	-	0.901
Northwest China	Xinjiang*	15.190	2.279	-	0.132	12.780
	Shaanxi	13.896	2.084	3.543	0.858	7.412
	Ningxia*	8.096	1.214	4.717	0.068	2.097
	Gansu*	3.240	0.486	-	0.090	2.664
	Qinghai*	2.102	0.315	-	0.004	1.783

* Denotes pasturing area

Table 1.21 Provinces with highest straw and stalk availability in 1995

Region	Rank	Availability for energy (million tons)
Shandong	1	44.310
Henan	2	30.034
Hebei	3	29.415
Jiangsu	4	28.984
Heilongjiang	5	25.996
Sichuan	6	23.620
Jilin	7	23.230
Anhui	8	16.910
Hubei	9	16.663
Inner Mongolia	10	14.890
Total		254.052

1.5 Grain and Livestock Production Forecasts for 2000 and 2010

1.5.1 Logistics of grain products in 2000 and 2010 and the straw and stalk Output

At the beginning of 1980's, agriculture in China began a steady development phase and the production of farm crops, forest, and livestock rapidly increased. During the Eighth Five-Year Plan, despite reductions in the cultivated area, and losses from natural disasters, grain production increased with an average annual growth rate of 1.4%. In 1991, grain production was 435.3 million tons, and increased to 466.6 million ton in 1995.

Developments in farming, forestry, animal husbandry, and fishery meet the needs of the continuously growing domestic market and the constantly improving quality of life. In addition, these developments increased incomes in rural and farm areas through restructuring programs and the use of advanced technologies. Agriculture in China faces many challenges because of reductions in the crop area, a poorly developed agricultural infrastructure, a lack of coordination between high-value economic crops and grain production, and a lack of resources to deal with natural disasters. Nevertheless, forecasts suggest that by 2000, the total grain output in China will be 500 million tons and by 2010, it will be 560 million tons *(Special Issues: Report of Sustainable Development Strategy Study in Rural Area*, Energy Consulting Programme of Chinese Science Academy of Engineering).

1.5.2 Logistics of livestock and product output

During the Eighth Five-Year Plan, production of all livestock products increased. In

1995, the total output of meat was 52.60 million tons, an increase of 67.3% from 1991; the output of eggs was 16.77 million tons, an increase of 81.8% from 1991; and the output of milk was 5.76 million tons, an increase of 24.1% from 1991. China's output of meat and eggs ranked first in the world. At the same time, the structure of livestock products continuously changed. The output of pork decreased from 78% in 1991 to 69% in 1995, while the shares of mutton and beef increased from 8.6% to 11.7%. In 1995, average meat consumption was 43.4 kg; average egg consumption was 13.8 kg; and average milk consumption was 4.8 kg.

Tables 1.22-1.24 list the 20 counties with the highest total production of pork, beef, and mutton and their distribution.

Table 1.22 Counties (cities) with the highest total products of pork, beef, and mutton (tons)

1	Sichuan	Zhongjiang	116,161	11	Hunan	Miluo	87,194
2	Sichuan	Anyue	100,732	12	Sichuan	Qianjiang	85,980
3	Jilin	Lishu	95,834	13	Hubei	Zhongxiang	85,355
4	Shandong	Caoxian	95,606	14	Hunan	Changsha	85,210
5	Hubei	Xiangyang	94,967	15	Shandong	Yuncheng	85,088
6	Sichuan	Jiangjin	93,658	16	Shandong	Pingduo	84,802
7	Liaoning	Changtu	93,209	17	Jiansu	Funing	84,320
8	Hunan	Shuangfeng	92,737	18	Hubei	Zaoyan	84,074
9	Hunan	Ningxiang	92,327	19	Jilin	Nong na	84,052
10	Hubei	Tianmen	89,027	20	Jilin	Yushu	82,846

Table 1.23 Distribution of ten counties (cities) with the highest total products of pork, beef, and mutton

Sichuan	3
Hunan	2
Hubei	2
Jilin	1
Shandong	1
Liaoning	1
Total	10

Table 1.24 Distribution of 20 counties (cities) with the highest total products of pork, beef, and mutton

Sichuan	4
Hunan	4
Hubei	4
Jilin	3
Shandong	3
Liaoning	1
Jiansu	1
Total	20

China expects that by 2000, the meat products will be 71.50 million tons, or 55 kg per capita; and by 2010, production will 99.40 million ton, or 70 kg per capita, basically. Per capita consumption of meat and mutton could be 6.44 kg by 2000 and 8.19 kg by 2010 (*China's Agenda 21*). Table 1.25 shows projected cattle population in 2000 and 2010, based on these data of increasing shares of both beef and mutton.

Table 1.25 Present and forecast cattle population in China

Region	Cattle population by year (million head)			Region	Cattle population by year (million head)		
	1995	2000	2010		1995	2000	2010
Beijing	0.141	0.210	0.267	Jiangxi	3.844	5.730	7.288
Tianjin	0.222	0.331	0.421	Shandong	12.393	18.475	23.495
Hebei	5.793	8.636	10.983	Henan	12.536	18.688	23.766
Shanxi	2.517	3.752	4.772	Hubei	4.095	6.105	7.763
Liaoning	3.016	4.496	5.718	Hunan	4.305	6.418	8.162
Jilin	3.843	5.729	7.286	Guangdong	4.715	7.029	8.939
Heilongjiang	5.115	7.625	9.697	Guangxi	7.971	11.883	15.112
Shanghai	0.069	0.103	0.131	Hainan	1.465	2.184	2.777
Jiangsu	0.991	1.477	1.879	Sichuan	11.159	16.635	21.156
Zhejiang	0.503	0.750	0.954	Guizhou	6.493	9.679	12.31
Anhui	7.013	10.455	13.295	Yunnan	7.861	11.719	14.903
Fujian	1.276	1.902	2.419	Shaanxi	2.781	4.146	5.272
				Total	150.017	164.157	208.765

The rapid increase in animal husbandry will also greatly increase total forage demand. The composition of demand will change with the rapid development of intensive animal rearing; the demand for commercial forage will increase, while direct use of straw and stalk will decrease. Use of commercial forage use will increase including ammoniation to compensate for the decrease in direct use. This assumes this increase offsets the decrease in direct use and that the daily consumption by one cow will still be 3.49 kg of straw and stalks.

Based on projected grain output, the total straw and stalk output in 2000 will be 648 million tons. The amount available for energy uses will be 351.9 million tons after deducting the 21 million tons projected for use in paper production, and allowing 97.2 million tons for fertilizer. This also assumes the percentage of the straw and stalk for forage will be nearly equal to 1995 at about 178 million tons. Table 1.26 lists the projected straw and stalk availability by region, and Table 1.27 shows the 10 provinces with the highest projected resource availability.

A similar calculation using the projections for 2010 shows the total straw and stalk resource will be about 726 million tons. Forecast grain output is 560 million tons less these allowances: 28 million tons for papermaking; 213 million tons forage and/or raw materials of forage processing; and 108.9 million tons for fertilizer and collection losses. The net amount for energy purposes will be 376.1 million tons, about the same amount projected for 2000.

Table 1.26 Straw and stalk resource distribution and availability in 2000 (million tons)

		Total straw and stalk output	Fertilizer and collection loss	As forage	As paper raw	As energy
National		647.923	97.188	177.447	21.000	352.288
East China	Shandong	76.662	11.499	20.011	1.082	44.070
	Jiangsu	38.622	5.793	1.600	0.592	30.637
	Anhui	32.650	4.898	11.324	0.459	15.970
	Zhejiang	12.030	1.805	0.812	0.508	8.905
	Jiangxi	14.564	2.185	6.207	0.529	5.643
	Fujian	7.714	1.157	2.060	1.094	3.403
	Shanghai	2.517	0.378	0.111	0.027	2.000
South China	Henan	61.138	9.171	20.242	3.776	27.949
	Hubei	28.473	4.271	6.612	0.696	16.894
	Hunan	22.818	3.423	6.951	1.138	11.306
	Guangdong	15.647	2.347	7.614	1.183	4.504
	Guangxi	16.940	2.541	12.871	0.361	1.167
	Hainan	2.485	0.373	2.006	0.016	0.091
Northeast China	Heilongjiang	41.575	6.236	8.259	0.708	26.372
	Jilin	36.720	5.508	6.205	0.928	24.079
	Liaoning	22.351	3.353	4.870	0.943	13.185
North China	Hebei	47.878	7.182	9.354	1.793	29.549
	Inner Mongolia*	18.788	2.818	-	0.231	15.739
	Shanxi	14.929	2.239	4.064	1.066	7.560
	Beijing	5.190	0.779	0.228	0.015	4.169
Southwest China	Tianjin	3.831	0.575	0.358	0.153	2.745
	Sichuan	48.551	7.283	18.019	1.618	21.632
	Yunnan	16.516	2.477	12.693	0.266	1.080
	Guizhou	12.631	1.895	10.485	0.075	0.176
	Tibet*	1.136	0.170	-	-	0.966
Northwest China	Xinjiang*	16.277	2.442	-	0.200	13.635
	Shaanxi	14.890	2.234	4.491	1.298	6.869
	Ningxia*	3.472	0.521	-	0.137	2.814
	Gansu*	8.675	1.301	-	0.103	1.292
	Qinghai*	2.252	0.338	-	0.006	1.908

Table 1.27 Ten provinces with highest straw and stalk resource availability in 2000

Province	Available for energy (million tons)	Order
Shandong	44.070	1
Henan	30.637	2
Hebei	29.549	3
Jiangsu	27.949	4
Heilongjiang	26.372	5
Jilin	24.079	6
Sichuan	21.632	7
Hubei	16.894	8
Anhui	15.970	9
Inner Mongolia	15.739	10

Table 1.28 Straw and stalk use and collection costs in three provinces in 1995

	Unit	Zhejiang	Shandong	Sichuan
Percentage of every straw use				
Raw material for paper	%	3.0	1	2.4
Forage	%	5.7	22	31.4
Fertilizer and collection loss	%	15	15	15
Available for energy	%	76.3	62	51.2
In which, burned as fuel		23.3	34	41.2
left in field		53	28	10
Total	%	100	100	100
Collecting radius	km	2	0.7-3.4	8, 5, 3*
Collecting cost				
Rice straw	Yuan/kg	0.15	0.2	0.15-0.20
Wheat straw	Yuan/kg	0.15	0.2	0.15-0.20
Cotton stalk	Yuan/kg	0.2	-	-
Rape stalk	Yuan/kg	0.14	-	-
Jute stalk	Yuan/kg	0.2	-	-
Corn stalk	Yuan/kg	-	0.12	-

Note: There are three types of collecting radius of straw and stalk in Sichuan Province: in plain area, less than 8 km; in mountainous area, less than 3 km; in hilly ground, less than 5 km.

1.6 Economic Analysis of Straw Availability

Table 1.28 summarizes preliminary survey work in Zhejiang, Shandong, and Sichuan Provinces on straw and stalk utilization and methods of collection. The collection radius and cost of collection are close related to the density of straw resources distribution and labor prices in areas. This results in significant differences in the collection radii and costs among the three provinces. In Zhejiang Province, the average collection radius is 2 kilometers (km), and the collection cost is 0.14 to 0.20 Yuan/kg. In Shandong, the radius is 0.7 to 3.4 km, with an average cost of 0.12 to 0.22 Yuan/kg.

Because of its terrain, Sichuan has three collection radii: 8 km on the plain; 5 km in low hills; and only 3 km in the mountains. The collection cost in Sichuan is 0.15 to 20Yuan/kg.

1.7 Conclusion

Constructing demand forecasts from the "bottom-up" has helped to estimate crop straws and stalks amounts in China and analyze their availability for energy purposes. These conclusions can be made:

- The amount of straw resource available in 1995 that could have been used for energy in 1995 was 355.1 million tons. This total is after deducting amounts used as forage, raw material for paper manufacturing, and fertilizer, and the amount returned to the field and straw collection losses. The estimated straw consumption of 415 million tons includes 190 million tons for fuel, 14 million tons for paper mills, 145 million tons for forage, and 91 million tons in collection losses.

- By 2000, the amount of straw available for energy use in China will be 352.28 million tons, which is nearly the same amount available in 1995.

- By 2010, total grain output in China will reach 560 million tons. Total straw and stalk production could be 726 million tons. Excluding the straw used for paper making, forage, fertilization, the amounts returned to the field, and collection losses, the total quantity of straw for energy use will be 376.1 million tons.

- Because straw and stalks are produced as by-products of food and feed production system, they are likely to be sustainable sources of biomass for energy. The projected amount available for energy in 2010 is essentially the same available today - in the range 350 to 370 million tons, or approximately 170 million tce. If used to produce electricity and process and space heating, in conjunction with gaseous fuels for cooking and daily living, there is a potential for 120 Gigawatts of power generation producing 450 Tera watt-hours (TWh) at reasonable efficiencies of conversion.

- Based on the ratio of straw for different uses, the ration of straw used as fuel relates to the level of economic development. In the regions with rapid economic development, the ratio of straw used as fuel is low, and the ratio of straw refused is high. For example, in Zhejiang Province, 30% of the straw is used as fuel (the lowest among the three provinces surveyed), while 60% of it is refused, which is a relatively high ratio.

- The collecting radius and cost are closely related to the density of straw resource distribution and labor prices in local areas. In the regions with high economic levels, the collecting radius is relative small and the collecting cost is high. Further study on economic efficiency and a detailed survey should be done, combined with project progress.

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CHAPTER 2 Research on Availability of Excrement Resources on Large and Medium-Size Domestic Animal Farms in China

In the past decade, along with the rapid development of economy and improved living standards, the Chinese government has paid much attention to the development of agricultural products that are important to people. The "Vegetable Basket Project" was launched, which led domestic animal farms in China to expand and modernize.

2.1 General Situation of Domestic Animal Husbandry in China

China has a long history of raising domestic animals. Many species of livestock and poultry are kept. There are two methods of feeding. One is natural feeding, the conventional method, which is suitable for small-sized farms and families, or for specific animals (sheep, horses, and ducks). Their excrement is scattered in grasslands and pools. The other method is concentrated feeding, demonstrated by large and medium-sized livestock and poultry farms. Cattle (including milk cows and beef cattle), pigs (including pork and boar), chickens (including egg hens and chicken as food) are generally raised in pens so that the excrement can be easily collected. This report only discusses cattle, pigs, and chickens kept on large-scale farms.

2.1.1 State-of-art of livestock and poultry raising in China

Table 2.1 summarizes cattle, pigs, and chickens raised and sold between 1985 and 1995.

Table 2.1 general information of raising livestock and poultry (1985-1995)

Year	Cattle (million)	Slaughtered fattened hogs (million)	Commercial chickens (million)
1985	68.82	238.75	523.69
1986	91.67	257.22	655.87
1987	94.65	161.77	787.78
1988	97.95	275.70	942.90
1989	100.75	290.23	1,077.91
1990	102.88	309.91	1,228.80
1991	104.59	329.87	1,610.20
1992	107.84	351.70	2,001.86
1993	113.16	378.24	2,393.16
1994	132.22	401.03	2,805.05
1995	132.06	480.51	3,057.51

Source: *Statistical Yearbook of China*

We can calculate the annual growth rate of cattle, pigs and poultry in different periods by the data in Table 2.1 (see Table 2.2). The growth rate for cattle has been low at only 4.7% during the last ten years. The investment for building large and medium-sized cattle farm is generally too high, and the length of time for the return of investment is too long. The price of imported milk cows is high and the operation cost is too high in farms with the more than 1000 cattle. Work cattle in villages are being replaced by agricultural machines and the raising of beef cattle is moderate. Raising of chickens and pigs has been rapid, especially in the last five-year period. In the first five years, people living in cities needed more and more meat and eggs because of improved living standards. In rural areas, however, the living standard did not improve as much, and there were not as many large farms in this period. In the last five years, as a result of the successful implementation of projects for living-food production, many villages have gradually grown into towns. Requirements for goods has changed dramatically, and milk is no longer regarded as a luxury food. This stimulates the raising milk cows. Lean pork is a favorite with urban people, which has accelerated the mechanization and modernization of pig husbandry. The need for chicken production has increased appreciably in the last five years. Many large and medium-sized poultry farms have been established.

Table 2.2 Growth rate of cattle, pigs and chickens

	Annual average growth rate (%)		
	1985-1994	1985-1989	1990-1994
Cattle	4.7	3.8	6.5
Pig	6.5	5.0	8.0
Chicken	20.5	19.8	22.9

2.1.2 Features of domestic animal raising in various regions in China

Cattle, pigs, and chickens are raised in 30 provinces, cities, and autonomous regions in China, as shown in Table 2.3.

Work cattle are mainly raised in the suburbs in rural areas, and milk cows are confined. Xinjiang and Inner Mongolia have the largest quantities of cattle in China, but the cattle are mainly kept by families or in or natural herds.

Sichuan Province produces a large number of pigs, but has no large and medium-sized pig farms. Pigs are mainly kept on small pig farms or by families. The pork produced is consumed totally within those areas and the surrounding provinces on the whole.

Shandong Province produces the most chicken, using multiple systems including large, medium, and small-sized farms, as well as single households. The large and medium-sized farms are located on the plains near cities, while small ones and

households are located in rural villages far away from cities and mountain areas.

Table 2.3 General information of raising cattle, pig and chicken in provinces (1994)

Area	Cattle (millions)	Sales of pigs (millions)	Commercial chicken (millions)
Beijing	0.15	4.0	139.67
Tianjin	0.20	1.4	158.87
Hebei	4.65	20.33	66.43
Shanxi	2.09	4.62	10.51
Inner Mongolia	3.65	4.59	18.00
Liaoning	2.61	12.54	121.05
Jilin	3.10	6.50	35.22
Heilongjiang	4.02	7.89	40.42
Shanghai	0.07	3.98	198.12
Jiangsu	0.86	25.80	27.02
Zhejiang	0.51	13.32	41.28
Anhui	61.90	14.23	5.12
Fujian	13.06	11.21	1.33
Jiangxi	3.74	21.17	4.20
Shandong	11.59	27.90	583.92
Henan	11.50	20.01	343.36
Hubei	3.81	25.16	425.98
Hunan	4.21	43.73	293.12
Guangdong	4.67	22.48	79.95
Guangxi	7.73	19.15	4.88
Hainan	1.42	1.91	3.86
Sichuan	10.69	71.86	148.65
Guizhou	6.30	9.55	1.95
Yunnan	7.69	12.35	2.23
Tibet	5.30	0.09	0.16
Shaanxi	2.66	7.37	30.42
Gansu	3.57	5.73	1.97
Qinghai	5.24	0.73	2.18
Ningxia	0.43	0.76	0.90
Xinjiang	3.37	0.001	14.29

Source: *Statistical Yearbook of China*

Table 2.4 Distribution trend and forms of keeping

	Area	Method of keeping
Cattle	Southwest China-Sichuan, Guizhou, Yunnan	Natural feeding, work cattle on the whole
	East China: Anhui, Hunan, Guangdon	Natural feeding and pens feeding is 50% for all
	North China: Shandong, Hebei, Henan	Mainly pen feeding, most of which are milk cows and work cattle
	North China: Hebei, Liaoning, Shandong	Large and medium pig farms
Pigs	East China: Jiangsu, Jiangxi, Hunan	Dominated by medium and small Sized pig farms
	Southwest China:-Sichuan, Yunnan, Guangxi	Mainly by household
Chickens	North China: Tianjin, Beijing, Liaoning,	Mainly by larger & medium type
	Shandong, Hebei	Most medium & small type
	East China: Shanghai, Guangdong	Mainly by larger & medium type

2.1.3 The sequence of domestic Animal number in different areas in China

Table 2.5 Sequence of number kept in different areas

	North China	Northeast China	East China	South China	Southwest China	Northwest China
Cattle	6	2	1	3	4	5
Pig	4	5	2	1	3	6
Chicken	3	4	2	1	5	6

2.2 Distribution and Features of Large and Medium-Size Poultry Farms in China

2.2.1 Distribution features of large and medium-size poultry farms

Farms are sparse in coastal areas with heavy population, such as Liaoning, Shandong, Jiangsu, Zhejiang, Fujian, and Guangdong provinces. These east coast areas and closed cities have high-density populations and advanced industrialization. They represent more than 50% of total milk, meat, and egg consumption.

Farms are mainly concentrated in the combined areas between large cities and rural areas, such as Beijing, Tianjin, and Shanghai. In general, large-scale farms are built in suburbs near big cities in order to satisfy the requirement of cities for high-quality meat, milk, and eggs and to reduce transportation losses.

Hence, up to 80% of China's large and medium-sized farms are concentrated on east coastal areas and in the vicinity of big cities, such as Beijing, Tianjin, Shanghai, and Guangdong. Fewer than 20% are in central China, and only 1% are in west areas such as Yunnan, Tibet, Qinghai, Sichuan, Xinjiang, and Gansu provinces.

2.2.2 Types of ownership of large and medium-size poultry farms

The ownership of large and medium-size poultry farms are classified as state-owned (agricultural reclamation system), collective, and private. State-owned milk farms make up more than 90% of the total and collectively owned milk cow farms represent about 10% of the total. There are no private milk cow farms. State-owned and collectively owned pig farms each make up 50%. State-owned poultry farms: make-up 30% of the total. Collectively owned farms make up 60%, and private farms make up 10%.

2.2.3 Regional distribution of large and medium-size farms

2.2.3.1 Distribution of large and medium-sized cattle farms

China's cattle husbandry has rapidly developed, especially in suburbs around big cities, where building modern intensive cattle farms is the best way rid poverty in rural area. In 1994, there were 132 million cattle. Only 3.84 million were milk cows, making up 2.9% of all cows. They were mainly scattered in Heilongjiang, Xinjiang, Inner Mongolia, and Hebei Provinces, and there is the maximum quantity of cows in Heilongjiang. Xinjiang and Inner Mongolia have 670,600 and 586,500 cows, respectively. Hebei has 438,100 cows. Milk cows in all four of these provinces make up 63% of the total and are mainly kept naturally.

According to some materials and suggestions from related administrative departments, farms with fewer than 100 cattle are small. Farms with more than 100 but fewer than 400 are medium, and those with more than 400 are large. Several farms with more than 1,000 cattle have been built.

China's large and medium-sized cattle farms are generally state-owned. Few are collectively owned, particularly in the milk cow husbandry. There are more than 500 large and medium-sized milk cow farms and 2,000 state-owned farms in China, most of which are cattle farms. Some farms even have more than two cattle farms. See Table 2.6.

2.2.3.2 Analysis by region in China

In the western and northwestern areas of China, except Xinjiang, cattle farms are not large, and the number is relatively small. The areas include Gansu, Qinghai, and Ningxia. In southwest China, Sichuan Province has the most milk cow farms because it has large population that needs a large quantity of milk. Sichuan's geographical position and climate are suitable for cattle and milk production. Generally the production units are small and farms with less than 400 cows are common. In other places southwestern areas, there are fewer big farms, but a lot of work cattle mainly kept by household.

Table 2.6 Distribution of state-owned large and medium sizedcattle farms in China

Area	Number of ftate-owned farms	Number of milk cow farms	Number of beef cattle farms
Beijing	16	34	2
Tianjin	14	23	4
Hebei	32	11	5
Shanxi	31	13	6
Inner Mongolia	138	46	46
Liaoning	141	10	15
Jilin	163	8	10
Heilongjiang	120	18	3
Shanghai	27	86	12
Jiangsu	26	8	1
Zhejiang	65	11	1
Anhui	24	7	0
Fujian	100	16	0
Jiangxi	131	7	0
Shandong	17	15	2
Henan	94	10	3
Hubei	48	9	0
Hunan	81	10	3
Guangdong	136	24	3
Guangxi	49	8	1
Sichuan	134	87	30
Guizhou	43	7	2
Yunnan	88	9	0
Tibet	6	2	3
Shaanxi	18	7	1
Gansu	18	2	0
Qinghai	16	2	9
Ningxia	15	2	0
Xinjiang	287	53	20
Total	2,078	535	185

In central China, the number of cows in large and medium milk cow farms are about 10% of the total. Farms are located in the suburbs of big cities (not including Inner Mongolia). The scale is not large either. Both milk cows and beef cattle are mostly kept free in rural areas in Inner Mongolia and Shanxi.

In east China, large and medium-sized cattle farms are concentrated, especially along the coast. A farm typically has more than 500 head, and milk cows are mostly imported. These good-strain cows are kept in modern farms with a high production of milk. There are farms of more than 1,000 cows in Beijing, Tianjin, Shanghai, and

Guangzhou, and other big cities. The state farm system plans to build 40 to 45 modern farms with more than 1,000 milk cows each.

The distribution of beef cattle farms is similar to that of milk cow farms. The numbers of cattle and farms are less than that of milk cows. The scale is relatively small. Beef cattle in north China are mainly free range.

2.2.3.3 Distribution of large and medium-sized pig farms

According to statistics, by the end of 1994, the number of all pork type pigs sold was about 420 million in China. Of those, 10% were kept on large farms. There are about 10,000 pig farms that keep more than 100 pigs. About 2,000 pig farms are large and medium-sized. Shanghai has 390 pig farms with 500 to 10,000 heads and Beijing has more than 1,500 pig farms with more than 200 heads. Tianjin has 10,962 pig farms (or households) with over 30 heads. Liaoning, Tianjin, Shandong, Jiangsu, and Guangdong all have large and medium-sized pig farms, as shown in Table 2.7. Pig farms with 10,000 heads will increase year after year. For example, the Ma Sanjia pig farm in Liaoning Province is one of China's large machined farms with 22,000 to 25,000 heads in pens. In 1992, one of the important projects determined by Tianjin municipal government was to a build lean pork base with 500,000 pigs. This project, involving 12 counties, was finished ahead of time in 1994 and accepted by check. In Shandong Province, 69 commercial lean pork type bases were built in 1994, among which 64 are national bases and five are provincial bases.

2.2.3.4 Distribution of large and medium-size poultry farms

Large and medium-sized poultry farms are general divided into poultry (chicken) and egg (hen) farms. The scale of poultry farms is larger than egg farms. Except Hainan, Guizhou, Tibet, and Qinghai, all other provinces, cities, and autonomous regions have many fair-sized poultry farms. Heilongjiang, Shanghai, Tianjin, Shandong, and Beijing have the most farms, which account for 61% of the total in China. Poultry farms are often as large as 100,000 to 300,000 in China, and farms of such size occupy 91.3% of all large and medium-sized farms. Farms with 300,000 to 1 million chickens make up just 6.2% of all large-sized. Large-sized farms with more than 1 million chickens are fewer, at only 2.5%. Shanghai has 33 farms, which is the maximum number in China. Tianjin has seven, and Heilongjiang, and Beijing both have five. Table 2.8 shows the distribution.

China's hen farms are relatively small in scale. Except Hainan, Tibet, and Qinghai, all other provinces, cities, and autonomous areas have hen farms on some scale. Beijing, Shanghai, Heilongjiang, Shandong, Tianjin, and Liaoning have the largest number of farms, representing 60% of the total. The scale of China's hen farm is commonly at the level of 50,000 to 100,000. Farms of this scale make up 66% of the whole country. Farms with 100,000 to 150,000 hens account for 21%. Those with more than 150,000 make up only 13%. Beijing has ten such farms. Liaoning, and

Shanghai both have eight. Table 2.9 shows the distribution of hen farms.

Table 2.7 Distribution of large and medium-sized pig farms in China

		Annual production		
Area	Total	500-1,000 head	1,000-5,000 head	Over 5,000 head
Beijing	240	77	115	48
Tianjin	140	53	63	24
Hebei	81	33	37	11
Shanxi	10	7	2	1
Inner Mongolia	8	6	2	0
Liaoning	125	96	25	4
Jilin	65	30	25	10
Heilongjiang	79	36	29	14
Shanghai	390	154	158	78
Jiangsu	153	54	69	30
Zhejiang	79	33	31	15
Anhui	28	14	9	5
Fujian	45	16	21	8
Jiangxi	42	36	5	1
Shandong	167	103	36	28
Henan	80	34	29	17
Hubei	25	9	12	4
Hunan	44	15	20	9
Guangdong	135	30	68	37
Guangxi	19	79	9	3
Hainan	2	20	0	0
Sichuan	51	2,318	18	10
Guizhou	9	6	3	0
Yunnan	12	7	4	1
Tibet	0	0	0	0
Shaanxi	7	5	2	0
Gansu	5	3	1	1
Qinghai	1	1	0	0
Ningxia	1	1	0	0
Xinjiang	2	1	1	0
Total	2,045	892	794	359

Table 2.8 Distribution of large and medium sized chicken farms in China

Area	Total	0.1-0.3 million	0.3-1 million	Over 1 million
Beijing	207	170	32	5
Tianjin	401	340	63	7
Hebei	172	166	6	0
Shanxi	11	6	3	2
Inner Mongolia	24	24	0	0
Liaoning	145	139	2	4
Jilin	8	7	0	1
Heilongjiang	446	438	3	5
Shanghai	428	385	10	33
Jiangsu	139	129	6	4
Zhejiang	61	61	0	0
Anhui	3	1	1	1
Fujian	11	7	4	0
Jiangxi	36	36	0	0
Shandong	202	187	15	0
Henan	176	166	6	4
Hubei	187	173	12	2
Hunan	4	4	0	0
Guangdong	8	3	3	2
Guangxi	23	21	2	0
Hainan	0	0	0	0
Sichuan	32	12	17	3
Guizhou	0	0	0	0
Yunnan	14	12	2	0
Tibet	0	0	0	0
Shaanxi	10	10	0	0
Gansu	1	1	0	0
Qinghai	0	0	0	0
Ningxia	3	2	1	0
Xinjiang	24	23	1	0
Total	2,785	2,523	189	73

Table 2.9 Distribution of large and medium-sized hen farms in China

Area	Total	50,000 to 100,000	100,000 to150,000	Over 150,000
Beijing	58	36	12	10
Tianjin	29	17	8	4
Hebei	12	8	2	2
Shanxi	9	5	2	2
Inner Mongolia	10	8	2	0
Liaoning	27	11	8	8
Jilin	6	2	3	1
Heilongjiang	40	34	4	2
Shanghai	48	32	8	8
Jiangsu	16	11	4	1
Zhejiang	10	7	2	1
Anhui	9	9	0	0
Fujian	5	5	0	0
Jiangxi	4	3	0	1
Shandong	31	23	5	3
Henan	23	13	7	3
Hubei	9	7	1	1
Hunan	6	5	1	0
Guangdong	10	4	3	3
Guangxi	2	2	0	0
Hainan	0	0	0	0
Sichuan	28	19	7	2
Guizhou	2	1	1	0
Yunnan	4	2	2	0
Tibet	0	0	0	0
Shaanxi	5	2	2	1
Gansu	4	2	2	0
Qinghai	0	0	0	0
Ningxia	1	1	0	0
Xinjiang	5	2	3	0
Total	413	271	89	53

2.2.3.5 Frequency of large and medium-sized farms by regions

Table 2.10 Frequency of large and medium-sized farms in different areas

	North China	Northeast China	East China	South China	Southwest China	Northwest China
Cattle	2	3	1	4	6	5
Pigs	2	4	1	3	5	6
Chickens	2	3	1	4	6	5

2.3 Current Situation and Prospects for Disposing of Excrement on Large and Medium-Size Farms

2.3.1 Excrement resources of China's main domestic animal

China's main domestic animals are cattle, pigs, and chickens to the analysis of availability of domestic animal's excrement. In 1995, the excrement resources were estimated at 850 million tons in physical quantity and more than 78 million tons of coal equivalence (TCE). This is based on factors such as animal type, weight, and amount of excrement by an animal during 24 hours a day, as described in Table 2.11.

Table 2.11 Amount of excrement of cattle, pigs and chickens and developable resource in 1995

	Cattle	Pigs	Chickens	Hens
Weight (kg)	500	50	1.5	1.5
Cycle of feeding (day)	365	150	60	365
Amount of excrement (kg/head/day)	20	4.0	0.1	0.1
Amount of excrement (tons/head/year)	7.3	0.6	0.006	0.0365
Number of animal (million/year)	132.22	481.03	1,200	1,800
Weight of excrement (million tons/year)	965.00	288.00	7.00	66.00
Coefficient of excrement collection	0.6	0.9	0.2	0.2
Amount of developable excrement (million ton/year)	578.00	259.00	1.00	13.00
Coefficient of conversion	0.47	0.43	0.64	0.64
Dry excrement content (%)	18.00	20.00	80.00	80.00
Amount for standard (million TCE)	48.90	22.30	0.51	6.66

2.3.2 Amount of animal excrement resources on large and medium-size farms

According to statistics in 1992, pigs in large and medium-sized farms represent 9.1% of the total amount in the country. Milk cows represent 43.4%, and chickens represent 15%. In the last three years, the proportion of livestock and animal farms has increased. Pigs on the large and medium-sized farms make up 10% of the total number, milk cows 40%, and chickens 20%. The amount animal's excrement resource on large and medium-sized farms is shown in Table 2.12. Because the excrement on large and medium-sized farms is generally flushed with water, the mixture of excrement and water is several times than the net excrement.

2.3.3 Status of excrement disposal on large and medium-sized farms

There are approximately 6000 large and medium-sized domestic animal farms in China. About 1 million tons of excrement (urine and foul water) are discharged every day. It is a main source of pollution and contains a great deal of organic matter

Table 2.12 Available amount excrement and water mixture on large and medium-sized farms in 1995

	Cattle	Pigs	Chickens	Hens
Number (millions)	1.71	48.00	240.0	360.0
Weight excrement and water mixtureper day (kg/animal)	50	12	0.3	0.3
Total weight of mixture per day (1,000 tons)	85.5	576	72	108
Cycle of feeding (days)	365	150	60	365
Total annual weight of mixture (million tons)	31.21	86.40	4.32	39.42
Coefficient of conversion	0.47	0.43	0.64	0.64
Dry excrement content (%)	8	7	27	27
Million TCE	1.173	2.843	0.747	6.812

Note: As for the amount of cattle's excrement, only milk cows are included. Beef cattle are kept in pens for very short periods each day, thus not much collectable excrement is collected.

such as bacteria and insect spawn. This situation should be harnessed at once. At present, however, only a limited quantity of excrement is under control. The main reasons are many farms are far from the city, the pollution does not attract people, and investment is too great for administration and there is difficulty in collecting funds. In Shanghai, for example, the city has more than 700 domestic animal farms that discharge 8,230 tons of excrement and foul water each day. That totals 3 million tons each year. About 40% of the mixture runs off directly, according to reports by the environmental protection department.

At present, only 20% of excrement and foul water have been processed to different degrees, and only 10% is processed through biogas projects mainly on cattle and pig farms. About 80% of all farms directly release feculency and sewage from farms. According to Chinese experience, the best way to harness feculency and sewage is to build a set device of anaerobe fermentation. This technology would not only save a lot of power, but would also create biogas. The discharged waste residue and liquid can be used in agriculture production, reducing the use of chemical fertilizer. A study shows that excrement from a pig weighing 50 kilograms can produce 0.2 m^3 of biogas. A cow can produce 1 m^3, and 100 chickens can produce 0.8 m^3. If used properly, excrement resource will become a promising alternative source of energy.

During the "Eighth Five-Year" Plan, the ordinary-temperature of anaerobe fermentation biogas project was mainly adopted, and the medium-temperature fermentation was an auxiliary project. The technology capacity is relatively mature, and the gas-generating rate has reached an international advanced level. For example, pig excrement can be processed in two steps, namely medium-temperature anaerobe fermentation and, ordinary-temperature fermentation. The gas-generating rate ranges from 1.5m^3/day to 2.2 m^3/day. Milk cow excrement uses anaerobe fermentation

technology in medium temperature to get biogas, and the gas-generating rate is 1.2 m^3 to 1.5m^3/day. Processing of chicken excrement requires high-temperature technology and other fuel to increase heat. It has obvious regional characteristics and high operating costs. Consequently, there are more biogas projects built on cattle and pig farms than on poultry farms.

2.3.4 Cases of using resource of excrement on large and medium-sized domestic animal farms

Shanghai Xinghuo Farm, is a large multiplex with 4,000 households. There are 2,900 milk cows on three cattle farms. They discharge 45,000 tons of excrement each year. Six biogas generation stations have been built. A total of 450 m^3 fermentation pools can produce 1.47 million m^3 of biogas to provide 75% of households (3,000) with living gas and can replace about 3,140 tons of coal each year.

In Shenzhen City, a large pig farm raises 6,500 to 7,000 heads annually, which produce about 200 m^3 of feculency and sewage each day. In 1991, a comprehensive pig excrement processing system was built. The feculency and sewage are processed through anaerobe fermentation, producing 210 m^3 to 320 m^3 of biogas and approximately 10 tons of organic fertilizer for flowers, vegetables, and fruit trees each day. The biogas can also heat pig houses and chicken coops and generate electricity, which can save 110,000 kilowatt-hours (kWh) and 60 tons of coal per year. The annual income of organic fertilizer is about RMB 240,000 Yuan.

2.3.5 Prospect of using excrement of domestic animals on large and medium farms

2.3.5.1 Development prospects for large and medium domestic animal farms

Considering the requirements of economic development, lifestyle improvements, and environmental protection in China, the development of domestic animal farms will intensify and expand. Before 2000, the number of domestic animal farms will not grow much, but number of domestic animal will increase. After 2010, the need for meat, milk, and eggs will tend to be stable, and feeding amounts will not change considerably. Table 2.13 shows forecasts for domestic animal farms.

Table 2.13 Domestic animal forecasts for China in 2000 and 2010

Animal type	2000	2010
Cattle (millions)	166.15	237.83
Pigs (millions)	658.34	998.95
Chicken (millions)	4,704.35	8,435.76

2.3.5.2 Prospect for domestic animal's excrement resources

Processed by anaerobe fermentation, the excrement of domestic animal can provide highly efficient, clean gas fuel, which has a greater heat value than coal gas in cities. The biogas project is an environmental project that can efficiently dispose of domestic animal excrement and is an energy project that provides clean and convenient fuel. It is a comprehensive project to change waste into energy and uses biogas at multiple levels to promote agriculturally and ecologically benign circulation. This project is also one of the important links and technologies that can achieve the continuous development of Chinese agriculture. Therefore in *Development Outline of Now & Renewable Energy*, the Chinese government set a goal for developing biogas projects. The number of households consuming biogas (including centralized gas) will be 7.55 million by the year 2000 and 12.35 million by 2010. In 2000, the biogas supply will be 2.26 billion m^3, equal to 1.8 million TCE. In 2010, the supply will be 4 billion m^3, equal to 3.14 million TCE. Based on this goal, predicted for the next 15 years suggest there will be great development of biogas projects using domestic animal excrement.

CHAPTER 3 Availability of Municipal Solid Waste Resources in China

The progress of social development and human activities continuously extorts from nature. The earth's resources are not always inexhaustible and available. In recent years, more people have begun to accept that the environment's capacity is limited. With the development of the modern civilization, high-consumption lifestyles have appeared. Because people consume large amounts of resources, they litter the surroundings with solid wastes. Through the years, this has caused serious environmental pollution.

People have begun to consider the correct consumption concept that the earth's resources such as mining oil, coal, and forests, are formed over undergoing hundreds or even billions of years. All of them are valuable resources that cannot be renewed. For example, based on the explored reserves of oil in the world and the growth rate of oil consumption, predictions suggest that oil exploitation will only last about 50 years. For industrialized countries, oil can be considered as the blood to keep them in operation. It is easy to imagine what people will face if oil is exhausted.

Meanwhile, resource consumption will bring about a variety of wastes. High consumption will generate more solid wastes, which are becoming increasingly complicated and difficult to process. High polymer organic substances in plastic waste will not decompose for 200 years or so. Pollutants in landfills will be stable after about several decades.

Thus, it has become a common view in the world that waste is also a usable resource. To protect the environment and to keep the right to share the earth's resources with future generations, people have begun to seek renewable resources from wastes. Especially since the western energy crisis in the 1970s, developed countries have put more emphasis on the use of urban waste as an energy resource. Therefore, advanced technologies such as classification and waste collection, waste incineration generation, landfill gas recycling, and others are actively promoted and developed to form and quickly develop a waste reuse resource industry.

3.1 Background

With rapid economic development and continuously improving urbanization levels and living standards, tons of urban living wastes be produced each day. Hence, the issue of environmental pollution has become serious. The disposal of urban waste is a

key factor influencing urban economic development and living standards. According to statistics, there were 640 cities in China from which 107.50 millions tons of urban waste were cleared and transported. That same year, industrial solid waste reached 645 million tons. Municipal residential solid waste accounted for 14.3% of total solid waste disposed in 1995; however, in 1991, the proportion was comparatively low, at 11.5%. The disposal ratio of wastes is less than one-third at present, and the ratio of harmless disposal and utilization as resources of wastes is lower.

The phenomenon of waste surrounding cities has occurred in many large cities such as Beijing, Shenyang, Shanghai, Xi'an, and others. Wastes not only take up land and damage scenery, they also spread diseases, which affect environmental sanitation and human health conditions. Therefore, disposing of wastes to reduce their quantities without harmful effects and reusing them as resources are important environmental issues in the cities of China.

Reuse of urban living wastes as resources can not only help China realize its goals of processing wastes and achieving sustainable use of resources, but can also create a new industry to protect environmental resources and meet societal and economic demands for sustainable development. Departments, enterprises, and institutions involved in the collection, transport, disposal and use of wastes as resources as well as comprehensive management of urban wastes comprise the whole system. This system involves many fields and integrates industrial technologies, social sciences, and comprehensive urban manage-ment. It is a symbol of physical and mental civilization of the whole society and secure to realize sustainable development of society and economy. Thus, it can build up urban environments free of waste pollution and form a benign cycle of resource reuse.

3.2 Developing Status and Existing Problem in Utilized Disposal Technology of Municipal Residential Refuse in China

3.2.1 There is great development of technologies while they are far from satisfying the demands of social and economic development

After a policy of reform and openness to the outside, there has been rapid development of disposal technologies for urban wastes in China. Many large cities have set up environmental and sanitation research institutions to form the technical forces and conduct basic science research in waste disposal, product research, and engineering development. Research and development in collection, transport, management, and disposal technologies and equipment greatly promote the development of urban waste disposal technologies in China.

During the Eighth-Five-Year Plan period, implementation of a research plan to

identify key technical problems and a wide study on technologies to use living wastes as resources resulted in significant achievements in pile fertilization, landfill, and incineration and waste utilization.

- ***Sanitary landfill technology***. Emphasis was on improving landfill techniques, sinking liquid disposal, landfill gas transfer utilization, and other key technologies.

- ***Waste incineration technology*****.** Shenzhen has successfully introduced and operated advanced waste incineration stoves abroad and identified key domestic technical problems. Domestic facilities and equipment, including waste feeders, ash dischargers, a combustion controlling facility, stoker, and a hydrochloric acid removal facility, have been used in the No.3 stove project. This project lay a solid foundation for the development of waste incineration generation technology.

- ***Compost technology*****.** It is important to improve compost set equipment technologies and adopt comprehensive use of products. A new market for compost disposal has appeared because of the development of organic fertilizer technology. Many special vehicles and machines have been developed to improve conditions for mechanizing environmental and sanitation works.

According to statistics, by the end of 1995, China had 640 cities, and they generated 107.5 million tons of urban residential wastes and 30.71 million tons of excrement. After establishing 609 disposal plants for waste and excrement, the disposal ratio of urban wastes increased from 11.9% in 1991 to 35.7% in 1994. This shows that the environ-mental and sanitation conditions in the cities have greatly changed from conditions in which urban areas were surrounded by waste.

However, the total level is very low for urban waste disposal technologies. Because of a shortage of funds, the maturity of technologies, dissemination level, and degree of application degree are also very low. This is especially true in the area of resource utilization. Lack of comprehensive development and engineering experience with new technologies and techniques mean the demands of different hierarchical areas cannot be satisfied. These include:

- Outdated machinery and auxiliary equipment for urban waste collection and transport and a low level of mechanization are unsuitable to meet the requirement of urban waste development and reuse.

- Disposal technologies are still in the initial stages of development. These technologies must be further developed and improved.

- The shortage of disposal equipment and its low production efficiency make it

impossible to develop large scale production.

Because of the need to use wastes as resources and gradually stricter environmental protection policies, environmental and sanitation engineering technologies have become comprehensive and highly technical areas that cut across all fields of engineering. Reuse technologies in landfill gases, high-performance and high-parameter waste incineration generation complement equipment, organic fertilization, landfill to seep-proof layer technologies, and others. In the next century, these will become the key technologies for the development of China's urban environmental and sanitation industry.

3.2.2 Auxiliary policies are needed to industrialize and commercialize the development of disposal technologies that use urban living wastes as resources

Traditional mechanisms and policies have not benefited the development of waste use technologies. Management of urban wastes, recycling of waste materials, and utilization of energy belong to different sectors, and must be managed separately. Because of lack of powerful policies, the waste reuse sector is withering. Not only does this seriously influence the operation and management of wastes disposal and utilization as resources, but also affects the development of the recycling industry. All these irrational factors limit the progress of industrialization, marketing and development of disposal technologies.

3.3 Resources and Distribution of Municipal Residential Solid Refuse

3.3.1 Refuse sources

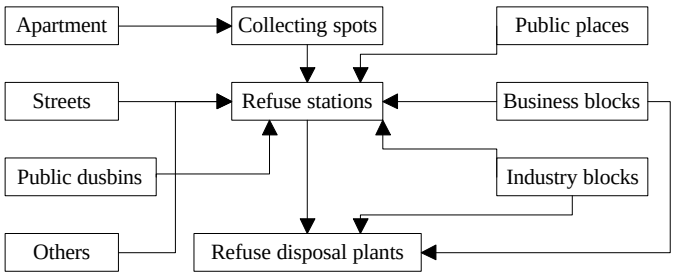


Figure 3.1 Sources of municipal solid waste

Daily residential living is the main source of solid refuse. Other sources are schools, hospitals, institutions and business blocks, public dustbins, and public places such as streets, parks, stadiums, and greenbelts. In addition, a fraction of construction waste may be mixed in with residential solid waste.

3.3.2 Resource of refuse

With the growth of cities and continued urbanization, urban solid refuse is increasing year by year. In the 1980s, annual increases in industrial solid waste were large; in the 1990s, these increases have been comparatively small. In 1991, industry produced 588 million tons of solid wastes, compared 645 million tons in 1995. At the same time, residential solid refuse was increased at an annual rate of 10%. In 1995, 107.5 million tons of residential refuse were cleared from China's 640 cities. Table 3.1 shows the increases in residential and night soil cleared in recent years.

Volume increases and changes in composition of municipal refuse primarily result from population growth and variations in consumption levels and structure. Other factors are the shares of clean vegetables and increased consumption of packaged foods.

Table 3.1 Resources of municipal residential solid waste

Year	1980	1985	1989	1990	1991	1992	1993	1994	1995
Residential disposal cleared (million tons)	31.32	44.77	62.91	67.67	76.36	82.62	87.91	99.81	107.50
Industrial solid waste (million tons)	-	525.90	571.70	578.00	588.00	618.80	617.10	617.0	644.80
Night soil disposal (million tons)	16.43	17.31	26.03	23.85	27.64	30.02	31.68	31.60	30.71

Source: *Statistical Yearbook of China 1996*

3.3.3 Resource distribution of refuse

In recent years, rapid economic development has quickly increased the level of urbanization in China. Cities are growing both in number and size. In 1995, there were 640 cities in China. Those with the populations less than 200,000 represented the largest ratio at 58.3%. The 192 cities with populations between 200,000 and 500,000 accounted for 30% of the total number of cities. Only ten cities have populations greater than 2,000,000, and they account for 1.6% of the total number of cities in China. Table 3.2 shows the scale and distribution of cities in China. In general, northern China has a greater number of highly populated cities than southern China.

In the last decade, solid refuse has increased at a rate of about 10%. Table 3.3 shows the residential refuse cleared in 1995 from all provincial capitals other large cities in China. The cities with large amounts of refuse cleared include Beijing, Shanghai, Harbin, Tianjin, Wuhan, and Guangzhou etc. All are large, developed cities and the refuse in these cities is greater than 1 million ton per city.

One hundred cities in nine provinces, including all provincial capitals, several large cities, and other medium and small cities, were analyzed to determine distribution and characteristics of municipal residential refuse in China. The nine provinces include Heilongjiang and Jilin in northeast China; Shaanxi in northwest China; Jiangsu, Zhejiang, and Fujian in east China; Jiangxi and Guangxi in south China; and Yunnan in southeast China. Table 3.4 shows statistics on populations using gas in households and residential refuse cleared per capita in these cities.

Table 3.2 Number of cities and populations

Region	Total	Population (10,000)				
		>200	100-200	50-100	20-50	<20
Total	640	10	22	43	192	373
Beijing	1	1				
Tianjin	1	1				
Hebei	33		2	3	6	22
Shanxi	20		1	1	4	14
Inner Mongolia	19		1	1	4	13
Liaoning	30	1	3	5	8	13
Jilin	27		2		11	14
Heilongjiang	30	1	1	6	10	12
Shanghai	1	1				
Jiangsu	43	1		4	17	21
Zhejiang	34		1	1	5	27
Anhui	20			3	8	9
Fujian	23			1	5	17
Jiangxi	20		1		7	12
Shandong	47		3	4	17	23
Henan	36		1	4	10	21
Hubei	34	1		3	11	19
Hunan	28		1	1	9	17
Guangdong	53	1		3	24	25
Guangxi	17			2	4	11
Hainan	7				1	6
Sichuan	36	1	1		14	20
Guizhou	12		1		3	8
Yunnan	16		1		2	13
Tibet	2					2
Shaanxi	13	1			4	8
Gansu	13		1		2	10
Qinghai	3			1		2
Ningxia	4				2	2
Xinjiang	17		1		4	12

Source*: Statistical Yearbook of China 1996*

Table 3.3 Urban residential refuse cleared from major cities in 1995

City	Residential refuse cleared (million tons)	Population (million)	Nonagricultural population (million)
Beijing	4.40	10.70	6.97
Tianjin	1.80	8.95	5.08
Shijiazhuang	0.51	8.46	1.78
Taiyuan	0.67	2.83	1.83
Huhehaote	0.45	1.78	0.79
Shenyang	2.33	6.67	4.15
Changchun	1.07	6.67	2.62
Harbin	2.06	5.34	3.19
Shanghai	3.72	13.01	9.22
Nanjing	0.77	5.22	2.59
Hangzhou	0.65	5.98	1.91
Hefei	0.22	4.11	1.22
Fuzhou	0.44	5.62	1.40
Nanchang	0.46	3.95	1.53
Jinan	0.56	5.42	2.22
Zhengzhou	0.58	5.84	1.84
Wuhan	1.66	7.10	4.07
Changsha	0.63	5.63	1.60
Guangzhou	1.55	6.47	3.95
Nanning	0.29	2.73	1.03
Haikou	0.25	0.48	0.39
Chengdu	0.88	9.72	3.01
Guiyang	0.45	1.68	1.15
Kunming	0.42	3.75	1.56
Lasha	0.06	0.38	0.13
Xi'an	0.70	6.48	2.56
Lanzhou	0.55	2.71	1.43
Xining	1.03	1.09	0.66
Yinchuan	0.17	0.89	0.48
Wulumuqi	0.82	1.44	1.18
Dalian	0.77	5.35	2.50
Ningbo	0.25	5.26	1.15
Xiamen	0.24	1.21	0.53
Qingdao	0.68	6.85	2.49
Shenzhen	0.48	0.99	0.75
Chongqing	0.95	15.20	4.06

Source: *Statistical Yearbook of China 1996*

Generally, in north China or in south China, for comparatively large cities, the living level and the gross domestic product (GDP) per capita are high, and the percentage of the population using gas in households is also high. However, the refuse cleared per capita is low. This is contrary to the trend in industrialized countries where municipal residential refuse per capita is increases as living levels improve. The main reason is the difference in living styles between China and developed countries. In many medium and small cities in China, especially in some small county-grade cities, the economy is still comparatively backward. Some households still burn coal directly to cook and heat their homes in winter. As a result, inorganic matter such as ash are a major component of residential refuse. Moreover, the amount of residential refuse increases. In regions of rapid economic development and lifestyle improve-ments, the distribution and com-position of urban residential refuse tends to show the transition to modern metropolises. These areas include Beijing, Shanghai, Guangzhou, and Shenzhen.

Table 3.4 also shows that per capita refuse in southern cities is comparatively lower than in northern cities of the same scale.

Table 3.4 Per capita urban residential refuse cleared from 100 cities in 1995

City Group (million)	>2	1-2	0.5-1	0.2-0.5	<0.2
Cleared refuse per capita (tons)	0.460	0.420	0.568	0.703	0.830
in north China	0.620	0.432	0.669	0.739	0.915
in south China	0.353	0.383	0.485	0.667	0.704
Percentage of population using gas in households (%)	85.3	77.0	57.9	52.0	53.2
in north China	89.6	81.8		42.8	66.1
in south China	81.2	72.6		61.2	42.9

Sources: *Statistical Yearbook of China 1996; Statistical Yearbook of Fujian Province 1996*; *1996; Statistical Yearbook of Guangxi Province 1996*; *Statistical Yearbook of Heilongjiang Province 1996*; *Statistical Yearbook of Jiangxi Province 1996*; *Statistical Yearbook of Jiangsu Province 1996*; *Statistical Yearbook of Jilin Province 1996*; *Statistical Yearbook of Shanxi Province 1996*; *Statistical Yearbook of Yunnan Province 1996*; *and Statistical Yearbook of Zhejiang Province 1996*

3.4 Urban Residential Refuse Composition

3.4.1 Refuse composition

Urban solid refuse is a mix of residential waste, waste from businesses and services, and a small amount of construction refuse. Refuse content relatively complicated. Factors such as residential living standards, energy structure, municipal construction, afforest-ation, and seasonal changes affect refuse composition. Table 3.5 details the contents of residential refuse in several major cities.

Table 3.5 shows that composition of refuse in large cities tends to reflect that they

have made transition to modern metropolises. The refuse has several characteristics:

Table 3.5 Contents of residential refuse in several major cities in China

City	Food	Paper	Plastics	Fiber, straw, and wood	Ash	Glass	Metal	Subtotal: Organic substance	Subtotal: Inorganic substance
Beijing	27	3	2.5	0.5	63	2	2	33	67
Tianjin	23	4	4		61	4	4	31	69
Hangzhou	25	3	3		5	2	2	31	69
Chongqing	20				80			20	80
Harbin	16	2	1.5	0.5	76	2	2	20	80
Shenzhen	27.5	14	15.5	8.5	14	5	5.5	65.5	24.5
Shanghai	71.6	8.6	8.8	3.9	1.8	4.5	0.6	92.9	7.1

- Organic content in refuse has reached or exceeded 1/3;
- Food waste in refuse makes up most of the organic refuse;
- Share of easily degradable organic content (food & paper) is large.

Generally, in cities where the rate of gas use for cooking is high, inorganic content in refuse is low. This is especially true in cities in north China. In buildings with central heating and gas, the organic content in refuse may be over 90% and more than inorganic matter.

3.4.2 Moisture content in refuse

Moisture content of mix solid refuse is defined as:

Weight of water in waste/(weight of water + weight of solid in waste) = moisture content

Table 3.6 shows the aquifer rate in various wastes. The aquifer rate of mixed refuse is about 10-30%. In highly urbanized cities, the food content in organic refuse is relative low, thus the aquifer rate of refuse is also low.

Table 3.6 Aquifer rates of urban residential refuse in China

Refuse category	Food	Paper	Plastics	Fiber	Rubber	Leather
Aquifer rate (%)	70	6	5	2	10	2
Refuse category	Wood	Glass	Cans	Metal	Dust	Courtyard waste
Aquifer rate (%)	60	20	3	2	7	15

3.4.3 Chemical content of refuse

Chemical elements are miscellaneous for complicated content of refuse. They primarily include: carbon(C), hydorgen(H), oxygen(O), nitrogen(N), and sulfur(S).

Table 3.7 shows the elements in some refuse.

Table 3.7 Chemical elements in some refuse contents (%)

Element	C	H	O	N	S	Cl
Food	43.52	6.22	34.50	2.79	<0.3	1.21
Paper	40.37	5.96	39.01	20.3	<0.3	<0.3
Plastics	82.90	13.20	0.96	<0.3	<0.3	<0.3
Fiber	48.36	5.58	39.59	<0.3	<0.3	<0.3
Wood, glass	40.54	5.85	33.34	1.66	<0.3	0.63

3.4.4 Caloric value of refuse

Refuse content varies greatly by living level and the condition of a city's infrastructure. Consequently, combustible refuse including plastics, rubber, leather, paper fiber, straw and wood organic substances also varies. Generally, in highly urbanized cities, combustible content is comparatively high because of the low content of inorganic substance in refuse and the low food content in organic substances. For a given city, the combustible content of waste varies. For example, refuse from hotels and diplomatic districts in Beijing contains relatively high amounts of plastic and paper, while refuse from hospitals contains primarily wrapping paper. In public utility and commercial sections, paper, straw, and wood make up most of the refuse, and combustible content and caloric value are comparatively high. Refuse from storied buildings with central heating and urban gas facilities is mainly composed of residue from kitchens and has a high aquifer rate. In some story house and waste yard districts, refuse mainly contains oven ash with low caloric value. At present, the average caloric value of municipal residential refuse in China is about 1,000 kilocalories/kilogram (kcal/kg).

Table 3.8 Caloric values of refuse from different sources in Beijing (kcal/kg)

Source	Building with central heating and gas	Superior apartment	Public utility	Hospital
Caloric value	1,083	216	2,367	1,805
Source	Commercial area	Single story house	Waste yard	Hotel
Caloric value	1,952	680	686	2,596

3.5 Status of Refuse Disposal

3.5.1 Summary

The start of urban refuse disposal occurred comparatively late in China, and the capacity for harmless refuse harmless is inferior. The phenomenon of refuse surrounding city has become severe. In recent years, China has made great progress

in the areas of environment and sanitation. The level of refuse disposal has improved and, on the whole, refuse surrounding China's cities has been controlled.

According to 1994 statistics, China's environmental and sanitation work force totaled 380,000, and the number of machines reached 34,400. The urban refuse disposal rate reached 35.8%, and a total of 609 harmless disposal plants had been built. In recent years, the capacity and rate of harmless disposal of urban solid refuse have increased notably. Organizations for environmental and sanitation research have been established in major cities in China. These organizations have made great efforts in the research of refuse disposal technologies and facilities. During the Eighth Five Year Plan, nearly 10 million Reminbi (RMB) Yuan worth of grants funds and millions more RMB Yuan in loans were used toward R&D and to demon-strate refuse fertilization, harmless landfill, incineration, and resource utilization.

3.5.2 Application of refuse disposal technology

Municipal solid refuse disposal is a comprehensive system that includes many sectors, such as refuse collection, transportation, transition, disposal, and resource utilization.

3.5.2.1 Collection of municipal solid refuse

At present, many cities in China use a mixed collection method (except for the refuse from hospitals). They collect refuse in fixed dustbins, mobile dustbins, garbage cans, plastics bags, closed clearing stations, and surface refuse stations. In most cities, residential refuse can be collected in a timely manner to keep the residential blocks clean.

3.5.2.2 Transportation of municipal solid refuse

On the whole, the rate of mechanical transportation of urban solid refuse in China is low. There are neither enough environmental and sanitation machines, nor are good quality machines available. Consequently, some sanitation staff work by hand, which is very labor intensive. Presently, about 40% machines, facilities, and mobiles in environmental and sanitation sector need to be replaced. As a result, about 10 million tons per year of urban solid refuse cannot be transported to disposal stations without delay.

3.5.2.3 Disposal of municipal solid refuse

At present, measures for refuse disposal and resource utilization in China are the same as in other countries. These primarily include sanitary landfill, composting, and incineration. In most cities, surface dumping, simple landfill, sanitary landfill, and mechanical compost are popularly used, and refuse incineration is also partly used in some regions.

Application of landfill. For the long term, cities in China commonly use natural dumps, natural landfills in pits and land level up for refuse disposal. However, in recent years, improved construction of landfill yards and a series of advanced landfill yards have been successfully completed. Many cities, such as Hangzhou, Guangzhou, Suzhou, Beijing, Chengdu, and Baotou have set up relatively perfect sanitary landfill yards, according to their respective situations. At the same time, collection technology and reuse of gas from landfill yards has also progressed a lot. At present, sanitary landfill is the main method for refuse disposal in China.

Application of fertilization. Refuse fertilization has been rapidly developed rapidly in China with relatively high research and application levels. Dual fermentation art has been applied since the 1980s. The process uses obligated blow and aerobic fermentation to shorten the primary fermentation cycle, consummate piling equipment, and promote industrialization of refuse fertilization. At present, domestically designed mechanical process lines for refuse fertilization based on Chinese conditions have been set up in several cities including Wuxi, Changzhou, Tianjin, Mianyang, Beijing, and Wuhan. Some simply equipped refuse fertilization plants are also in operation.

Application of incineration. Research on incineration of solid refuse began in China in the mid-1980s. Currently, refuse incineration most effective method of harmless decrement disposal and solid waste resource use. To date, refuse incineration plants have been built in cities such as Shenzhen, Leshan, Xuzhou to demonstrate refuse incinerated generation, and they are in good running condition. However, these plants are not large in scale and have low daily disposal capacity. Some large cities such as Beijing, Shenyang, and Guangdong plan to build larger-scale refuse incineration plant.

Table 3.9 Disposal of municipal residential solid refuse in China in 1995

Type	Quantity (tons/day)	Ratio (%)
Surface dumping & simple landfill	232,520	78.95
Sanitary landfill	51,073	17.34
High temperature compost	7,095	2.41
Incineration	2,000	0.68
Others*	1,832	0.62
Total	294,520	100

* Includes refuse-based construction materials and comprehensive utilization of refuse.

3.6 Status of Refuse Resource and Disposal in Several Cities

3.6.1 Beijing

With the development of the city, improved consumption levels, and increasing population, the amount of urban refuse has increased year by year in Beijing. Presently, the amount of urban residential refuse dumped daily is 12,800 tons. The annual discharge of residential refuse is roughly 4.7 million tons, excluding construction refuse, recycled, and waste material.

In the mix of residential refuse in Beijing, organic substances make up about 33%, mainly including food, paper, plastics, straw, and wood. Inorganic substances make up 67%, mainly including brick, dust, and metal. The aquifer rate is about 15%. Refuse content varies greatly with living level and the condition of the city's infrastructure. Consequently, combustible content in refuse is also quite variable. The caloric value of refuse in Beijing may reach 1,000 kcal/kg.

Generally, the residential refuse in Beijing can be cleared, collected, and disposed timely a timely manner. The methods of refuse collection mainly include garbage can stations, dustbin stations, surface refuse stations, closed clearing stations, and rear-loading compressed refuse mobiles. As the urban area is relatively far from the dump sites, refuse collected from the original places must be moved to transit stations by mobile collections, then it is transported to the designated landfill sites or dump sites. At present, there are eight simply equipped refuse stations in Beijing.

By now, Beijing has adopted three methods of dumping, landfilling and utilization of refuse disposal. About 25% of refuse is lmoved to landfills, and 3% of the refuse are reused. Other refuse is openly dumped.

Beijing now has four refuse dump sites that occupy relatively large areas. They are Lishuiqiao Dump Site, Dagao Dump Site, Nangong Dump Site, and Sujiatuo Dump Site. Beijing also has five landfill plants: Asuwei Refuse Landfill Plant, Beishenshu Refuse Landfill Plant, Anding Refuse Landfill Plant, Lixian Refuse Landfill Plant, and Dahuichang Refuse Landfill Plant.

In addition, Beijing has a mechanical refuse fertilization plant, a simply equipped fertilization plant, and a refuse-based brick-making plant. The refuse for utilization totals 470 tons per day.

Figure 3.2 Distribution of refuse disposal plants in Beijing

3.6.2 Shanghai

There is great difference between Shanghai and Beijing in the constitution of residential refuse. In Shanghai, the organic matter in refuse including food, paper, rubber, plastics, textile, straw, and wood is the major part in residential refuse in Shanghai. Food waste, which makes up more than 70% of mixed residential refuse also is a main part of organic matter. Compared with the residential refuse in Beijing, brick, tile, stone and ash represent a relatively small ratio of Shanghai's residential refuse. Therefore, the ratio of combustible matter is high in Shanghai's refuse. With high ratio of food waste in refuse, the aquifer rate is high in mixed refuse and can reach 53%. The major chemical elements include carbon, hydrogen, oxygen, and nitrogen, with a small amount of sulfur and ash.

In 1995, the total residential waste cleared in Shanghai reached 3.72 million tons, of which 2.835 million tons were disposed in a harmless manner. The harmless rate disposal was 76%. Two waste and night soil disposal plants have been built in Shanghai with a total capacity of 7,000 tons/day.

3.6.3 Shenzhen

Residential refuse in Shenzhen, contains more organic than inorganic matter, and food waste also represents a large ratio. With increased living levels and changes in living and consumption styles, the aquifer rate of residential refuse is decreasing. At the same time, the caloric value of refuse is also increasing.

In the area of harmless decrement disposal and resource utilization of municipal

residential refuse, Shenzhen started comparatively early. At present, a refuse incineration plant with a 300-ton/day capacity is in operation. In addition, two other plants are being built in Shenzhen: a large, no-harm landfill plant which will have an 1,800-ton/day capacity and a large incineration plant which will have a 600-ton/day capacity,

3.7 Forecast of Municipal Solid Refuse Resource in China

3.7.1 Forecast development of urbanization and urban population

With recent economic development, the number of cities and towns has increased and the scale of cities has been growing. Moreover, taking into account natural population growth, urban populations are expected to increase at a relatively high rate in the next coming 20 to 30 years. In 1995, 70% of population still lived in rural areas; however, estimates suggest that urban population will be a major part by 2010 to 2020.

Based on the basic conditions of population forecasts, as shown in Table 3.10, urban population and its distribution are shown in Table 3.10 and Table 3.11, respectively. Two factors are considered in the population forecast, namely the natural population growth rate and the ratio of rural population immigrating to urban areas.

Table 3.10 Basic Conditions and Results of Scenario of Population Forecast

Year	Total population (million)	Urban population (million)	Rural population (million)	Natural population growth rate	Ratio of rural population immigration to urban areas
2000	1300	454	846	0.0130	0.15
2010	1420	654	766	0.0089	0.14
2020	1490	820	670	0.0048	0.11

Source*: Study on China Energy Strategy (2000-2050)*

Table 3.11 Forecast of urban population distribution (million)

Region	1995	2000	2010	2020
North China	46.1	61.4	83.7	102
Northeast China	52.2	69.6	102	129
East China	93.2	124	177	220
Middle China	52.5	69.9	102	130
South China	27.8	37.0	54.2	68.6
Southwest China	41.8	55.6	81.5	103
Northwest China	27.5	36.5	53.6	67.8
Total	341	454	654	820

3.7.2 Forecast of economic development

Since the 1990s, China's economy has developed rapidly, with about an 8% growth in per capita GDP in recent years. Considering China's overall target for future economic development, the Table 3.12 shows predicted future economic development, according to the chapter "Development Prospect of Economy and Society" in *Study on China Energy Strategy*.

Table 3.12 Forecast of economic development in China (constant price in 1995)

Year	1995	2000	2010	2020
GDP per capita (RMB Yuan)	4,754	6,921	11,824	20,422

Source: *Study on China Energy Strategy (2000-2050)*

3.7.3 Forecast of resource and distribution of municipal residential refuse

The amount of municipal residential waste is related to many factors. Based on the experiences in developed countries, in general, as income and consumption increase, and as composition of consumption and lifestyles change, the amount and composition of municipal residential refuse also changes. Table 3.13 shows per capita residential refuse per capita in some countries. It shows different income levels and in several typical cities in the mid-1980s.

Table 3.13 Per capita refuse by income level in selected world cities in the mid-1980s (kg/day)

Income Level	High-income			Mid-income		Low-income	
Quantity of Refuse	0.7-1.8			0.5-0.9		0.3-0.6	
City	Tokyo	Vienna	Seoul	Hong Kong	Singapore	Lima	Rio de Janeiro
Quantity of Refuse	2.7	1.0	2.53	0.85	0.87	0.96	0.54

Table 3.13 shows that although the quantity of residential refuse is related to residents' incomes, (that is the higher the income, the more refuse), per capita refuse varies greatly. These variations result from the differences in natural conditions, lifestyles in different countries, and other factors. Refuse resources in China cannot be predicted based on such data directly. According to the local conditions in China, the data from Beijing in recent years are used as the base in this scenario. The reasons for selecting Beijing include its suitable geographic location, its comparatively high level of economic development, its current development level, and lifestyles among the resident. These reflect, to a degree, the tendency future development in other Chinese cities. Table 3.14 and Figure 3.3 show the relationship between the GDP and per capita residential refuse in Beijing from 1990 to 1995.

Table 3.14 Per capita GDP and per capita residential refuse in Beijing (1990-1995)

Year	1990	1991	1992	1993	1994	1995
GDP per capita (RMB Yuan, constant price in 1995)	8,700	9,653	10,530	11,366	11,592	13,073
Residential Refuse Per Capita (kg/year)	597	598	603	613	621	631

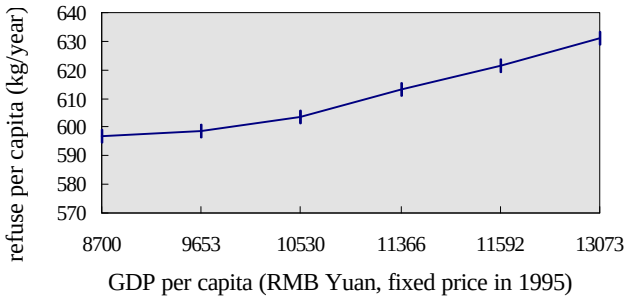


Figure 3.3 Relation between GDP per capita and residential refuse per capita in Beijing (1990-1995)

Table 3.15 Forecast of refuse resource and distribution in China (million tons)

Region	2000	2010	2020
North China	24.9	37.0	50.4
Northeast China	28.3	45.1	63.8
East China	50.4	78.1	108
Middle China	28.4	45.3	64.1
South China	15.0	24.0	33.9
Southwest China	22.6	36.0	51.0
Northwest China	14.8	23.7	33.0
Total	184	289	405

Based on the above assumptions, refuse resources in the next 20 to 30 years can be predicted, as shown in Table 3.16. This shows that the amount of municipal residential refuse in China will increase rapidly. The result of this scenario is a little more than the result of prediction of refuse made by the major environmental protection departments of China Table 3.17 shows predicted municipal refuse in China.

At present, the amount of municipal residential refuse is increasing at the rate of 10% annually. According to the forecast of environment protection departments in China, which is based on the growth rate of refuse in recent years, the amounts will

reach 151 million tons by 2000; 230 million tons by 2010. The rate of harmless disposal will be 60% by 2000 and 90% by 2010.

Table 3.17 Forecast of municipal residential solid refuse in China

Year	2000	2010
Refuse cleared (million tons)	151	203
Harmless disposal rate (%)	55-60	85-90
Harmless disposal quantity (1,000 tons/day)	31	54

In the near future, most cities in China will face the great task of determining how to dispose of increasing amounts of residential refuse and make full use of these resources. Demand for refuse disposal technology and market will be substantial. Disposal of municipal refuse is a large project and should be disposal according to the local conditions.

CHAPTER 4 Research on Availability of Forest Resources and Wood Residues in China

4.1 Introduction

Forestry is an important basic industry in China's national economy. Viewed from the standpoint of environmental protection, forestry has many functions, which include climatic adjustment, water and soil conservation, water resource con-servation, wind breaking, sand binding, and maintaining the ecological balance.

Viewed from an economic standpoint, the development of forestry can regulate the industrial structure in rural areas. It is also a key link for the sustainable development of agriculture. Additionally, national economic growth requires a great deal of timber and a variety of forest products. Thus, the development of forestry will play an important role in helping poor and remote areas to become economically competitive.

4.2 State-of-the-Art of Forestry Resource in China

China covers 9.60 million square kilometers of land. Of that amount 70% is mountainous area, and 16% is desert. The amount of forest coverage increased from 8% percent in the early founding of the People's Republic of China to 13.9% today. However, compared with the world average, China's per capita forested area is only 1/6 of it. Table 4.1 shows amounts of forest area in China in various years.

Table 4.1 Afforested areas in China in selected years (1,000 hectares)

Year	Afforested area
1953	1,112.93
1960	4,143.93
1970	3,884.00
1980	4,552.00
1990	5,208.47
1991	5,594.47
1992	6,030.40
1993	5,903.40
1994	5,992.66
1995	5,214.61

Source: *Chinese Forestry Yearbook 1996*

From Table 4.2, which shows China's forest distribution by region, we can conclude that the largest afforested area is in north China, followed by the areas in the

southwest. Because of high population density in east China and many large and medium-size cities, east and northeast China are relatively less afforested. In addition, there is a wide water field and a large area covered by low and small plants and a small forest area. Northwest China is plateau with more sands and yellow soil. The dry climate makes it difficult for plants to grow; thus there are no large forest areas. Figure 4.1 shows that the total afforested areas in the north, northeast, and east regions of China are very close to the total in south, southwest and, northwest China.

Table 4.2 Afforested areas in China by regions and forest type (1,000 hectares)

Region	Total	Timber forest	Economic forest	Shelter forest	Fuelwood forest	Special purpose forest
Total	5,203.37	1,833.01	1,969.85	1,240.44	145.26	14.81
Beijing	28.64	0.92	11.70	14.47	0.09	1.46
Tianjin	4.81	0.40	0.95	3.46	-	-
Hebei	448.81	102.38	187.58	148.62	10.08	0.15
Shanxi	405.17	128.58	171.41	104.61	0.30	0.27
Inner Mongolia	429.31	114.97	64.90	243.96	5.47	0.01
Liaoning	201.09	45.68	67.66	70.33	16.63	0.79
Jilin	66.24	34.17	16.07	15.33	0.61	0.06
Heilongjiang	278.52	176.31	33.41	54.09	9.67	5.04
Shanghai	1.40	-	1.23	0.17	-	-
Jiangsu	27.20	12.44	11.30	3.36	0.03	0.07
Zhejiang	41.33	13.96	23.38	2.09	1.88	0.02
Anhui	72.50	27.17	42.21	1.68	1.41	0.03
Fujian	41.74	15.64	7.64	6.83	11.63	-
Jiangxi	250.09	143.98	54.76	37.30	13.17	0.88
Shandong	308.03	25.91	229.86	50.08	1.67	0.51
Heinan	292.72	122.47	102.44	65.95	1.67	0.19
Hubei	271.63	99.32	136.69	21.67	13.72	0.23
Hunan	148.73	59.03	73.36	14.92	1.14	0.28
Guangdong	20.68	9.12	6.73	2.78	1.00	1.05
Guangxi	166.25	63.81	100.22	1.73	0.49	-
Hainan	17.91	7.46	8.18	1.69	0.57	0.01
Sichuan	360.03	139.95	127.16	86.54	5.45	0.93
Guizhou	285.10	162.20	97.55	23.75	1.30	0.30
Yunnan	391.38	190.38	125.03	63.94	11.00	1.03
Tibet	23.07	3.07	20.00	-	-	-
Shaanxi	337.39	86.92	145.93	96.38	7.85	0.31
Gansu	169.76	32.74	73.14	48.53	14.44	0.91
Qinghai	28.01	5.52	1.71	12.07	8.71	-
Ningxia	26.83	3.41	4.54	18.19	0.69	-
Xinjiang	59.00	5.10	23.11	25.92	4.59	-

Source: *Chinese Forestry Yearbook 1996*

Given the distribution of forest types, economic forests and timber forests make up a large proportion, representing about 38% and 35%, respectively. In 1995, economic forest production developed continuously and made up about 42.6% of the total manmade forests. Fast growing and high-yield timber forest covered 0.3769 million hectares (ha) among timber forests, representing 20.45% of timber forests. Shelter forests were 24% of the total manmade forests. The "Three North" shelter forests, which rank first and second, are along the upstream of the Yangtze River and the coastal shelter forest. Fuelwood forests and special purpose forests share a very small proportion. Liaoning, Gansu, Hubei and Jiangxi are the top four provinces for fuelwood forest area. The two largest areas for special purpose forests are in Heilongjiang and Beijing.

China's Ministry of Forestry has proposed that by the end of this century, forest coverage should reach 15.5%, and by 2010, it should reach 17.5%.

4.3 General Situation of the Forestry Industry in China

Wood production in China follows the Formulation of the Annual Logging Quota, and the wood outputs in each area are completed according to the production plan made by the Government of China (GOC). Based on historical development, the output of timber and bamboo have increased year by year, and the wood production has also increased, as shown in Table 4.3.

Table 4.3 Output of timber, bamboo, and wood products in China by year

Year	Timber (million m^3)	Sawnwood (million m^3)	Bamboo (million root)	Plywood (m^3)	Fiberboard (m^3)	Shaving board (m^3)
1953	17.54	6.64	26.43	35,353	-	-
1960	41.29	16.23	88.69	147,575	59,571	-
1970	37.82	11.00	69.58	170,684	54,706	14,989
1980	53.59	13.69	96.21	329,900	506,200	78,200
1990	55.71	12.85	187.14	758,700	1,172,400	428,000
1991	58.07	11.42	291.73	1,054,000	1,174,300	613,800
1992	61.74	11.19	404.30	1,564,700	1,444,500	1,158,500
1993	63.92	14.01	433.56	2,124,500	1,809,700	1,571,300
1994	66.15	13.94	504.30	2,606,200	1,930,300	1,682,000
1995	67.67	41.84	447.92	759,264	2,163,962	4,351,115

Based on distribution of wood output in China by area, the north region has the largest output, especially the Daxing'anling Mountains and Xiaoxing'anling Mountains in Heilongjiang Province. This is the main wood-growing district, representing 18% of the country's output. The next largest are Jilin Province, with 8.7% of the total, and Inner Mongolia Autonomous District, with 7.8% of the total. In the south areas, wood is mainly produced in Fujian, Sichuan, and Guangxi Provinces. The outputs are 8.2%, 6.86%, and 6.2%, respectively. The provinces of

Shandong, Heilongjiang, Hubei, and Guangdong produce sawnwood. Bamboo mainly distributes in the south areas, with high yields in Zhejiang, Guangdong, Fujian, and Yunnan provinces. Table 4.4 summarizes outputs by region.

Table 4.4 Total output of timber and wood products by region

Region	Timber (million m^3)	Sawnwood (million m^3)	Bamboo (million root)	Plywood (m^3)	Fiberboard (m^3)	Shaving board (m^3)
Total	67.67	41.84	447.92	759.26	216.40	435.11
Beijing	0.05	0.23	-	1.08	2.41	1.95
Tianjin	-	0.08	-	9.78	3.60	3.75
Hebei	0.54	1.36	-	79.44	12.20	27.41
Shanxi	0.35	0.08	-	3.11	0.99	2.44
Inner Mongolia	5.30	1.71	-	3.84	3.25	11.35
Liaoning	1.51	3.58	-	11.35	11.11	6.77
Jilin	5.91	1.43	-	10.44	6.30	20.80
Heilongjiang	12.14	5.86	-	40.20	12.66	28.21
Shanghai	-	0.18	-	10.49	4.86	0.66
Jiangsu	0.77	1.86	8.85	76.85	10.49	33.89
Zhejiang	2.34	0.85	91.61	30.51	13.84	6.54
Anhui	2.22	1.09	14.57	56.62	2.67	12.91
Fujian	5.57	2.06	71.03	76.32	13.49	10.42
Jiangxi	2.69	1.31	10.69	20.56	5.34	6.99
Shandong	1.53	7.06	-	158.89	23.98	115.62
Heinan	1.96	0.39	-	42.83	13.81	25.23
Hubei	2.33	4.30	13.39	50.71	12.06	21.78
Hunan	3.23	0.57	38.61	16.84	6.88	12.33
Guangdong	3.07	3.02	71.80	24.99	27.09	23.38
Guangxi	4.22	1.00	60.66	5.02	8.83	9.66
Hainan	0.45	0.66	-	1.41	-	2.62
Sichuan	4.64	0.68	11.04	6.75	5.80	18.03
Guizhou	0.77	0.14	0.96	2.00	1.39	0.43
Yunnan	3.91	0.72	52.76	8.49	3.74	7.13
Tibet	0.20	0.11	-	0.03	-	-
Shaanxi	1.06	1.03	1.94	9.54	6.66	18.52
Gansu	0.51	0.08	0.02	0.61	0.47	1.07
Qinghai	0.07	0.02	-	0.17	0.38	0.35
Ningxia	0.08	0.06	-	0.09	0.37	2.33
Xinjiang	0.28	0.31	-	0.30	1.73	2.54

Source: *Chinese Forestry Yearbook 1996*

The south and southwest areas have the largest outputs of timber and sawnwood. In these areas, the outputs of timber is about 29% and 25% of China's total, respectively, and the outputs of sawnwood is 26% and 40% of the total, respectively. The next largest is the northeast area. Output is the smallest in northwest area, representing just 3% to 4% of the total. Output distribution is almost as same as afforested areas.

Figure 4.1 illustrates the output of wood products in different areas. The southwest, with 40% of the total, has the highest plywood output in the country, followed by the northeast, with 36% of the total. Plywood output is lowest in the northwest and the north regions, with 1% and 2%, respectively. Fiberboard output has no obvious difference by region. In the southwest, it is 44%, while in the northwest, it is 23%. Fiberboard outputs in south central, north, east, and northwest China are 14%, 10%, 5% and 4%, respectively. The southwest region has the country's largest output of shaving board at 48%. Shaving board output in the northeast area is 16%, while in the south it is 13%, and in the north, output is 11%. Both the northwest and east have a 6% share of the shaving board output.

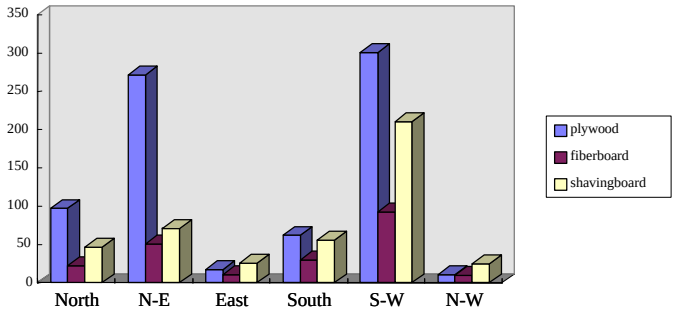


Figure 4.1 Output of wood products by region

4.4 The Timber Residue Situation in China

4.4.1 The wood consumption situation in China

According to Table 4.5, wood consumption is divided into three main parts. Merchantable wood accounts for about 44.2% of total wood consumption and includes state allotted share at 2.9% and selling wood at 32.1%. Special purpose wood represents 23.5% of total consumption. Wood burned directly represents 28.8% of the total, of which about 26.4% is fuelwood. Other consumption accounts for about 3.5%, and includes about 1.7% of felling wood lost to theft.

Table 4.5 Wood consumption in China (10^6 m^3, 10^6 pieces)

Items consumed		Total	Percent of consumption	in which	
				Wood which is not four-sided	Four-sided wood
Total wood consumption		298.429	100.0	281.833	16.596
Merchantable wood	Total	131.743	44.2	128.63.8	3.105
	National allotment	8.472	2.9	8.472	-
in which	Sale out province	37.973	12.7	37.806	0.167
	Sale in province	57.833	19.4	56.965	0.868
	Enterprise own-use	7.714	2.6	7.685	0.029
	Other	19.751	6.6	17.710	2.041
Own-use wood	Total	70.179	23.5	57.548	12.631
in which	Farmer own-use	62.018	20.8	49.387	12.631
	Cultivation	8.161	2.7	8.161	-
Fuel wood	Total	85.936	28.8	85.325	0.611
in which	Rural	69.429	23.3	68.818	0.611
	Urban	9.294	3.1	9.294	-
	Sideline	7.213	2.4	7.213	-
Other reasons	Total	10.571	3.5	10.322	0.248
	Forest-fire	0.668	0.2	0.668	-
in which	Insect pest	1.406	0.5	1.197	0.209
	Other disaster	1.133	0.4	1.131	0.002
	Steal loss	5.276	1.7	5.239	0.037
	Others	2.088	0.7	2.087	-
Bamboo		459.322	-	451.702	7.620

4.4.2 The situation of wood residue

Because of the differences in wood processing sites, processing technology, and wood products, available wood residue can be classified into two types: residue from felling areas and residue from processing factories.

4.4.2.1 Residue from felling areas

The residues from felling areas include branches and twigs, brush, dead wood, wounded wood, and abandoned wood. According to statistics, residue shares about 30% of every 100 cubic meters (m^3) of wood, which includes about 15 m^3 branches and twigs and 8 m^3 truncated wood and some small stalk.

In 1995, about 67.669 million m^3 of rough timber were produced, leaving 20.301 million m^3 of residue available. Calculated by the utilization rate of 55%, about 10 million m^3 residues will be available for processing. This will ease the imbalance between wood supply and demand, and will mitigate the forestry resource shortage.

For example, in the Daxing'anling forest region, the average storage capacity of the residue per hectare is about 8.44 m^3, which includes wood more than 5 centimeters in diameter and greater than 1 meter in length. Loss occurs during collection, loading,

and transportation of felling residue. The loss rate is 7%, or about 0.59 m^3 per ha. The residue resource that can be used is about 7.85 m^3 per ha. Because Daxing'anling is an old forest region with a long history of felling, an advanced operating process, and a forest management system, the percentage of wood residue is lower than the national average. In Daxing'anling the prestreak output per hectare is 70 m^3, and residue accounts for 21% of that output. Based on the figures above, there will be 73,500 m^3 in residues in a Forestry Bureau with an annual wood output of 350,000 m^3. Felling residue is a great resource that is not being fully used.

4.4.2.2 Residue from wood processing factories

In China, almost all production lines in wood processing factories use ring-driven band saws. These lines can process prestreak of various diameters, shapes, and internal characteristics. They can produce both common processed timber and special timber. However, the single production lines have no timesaving advantages.

Bands for the sawing machines tend to be unstable, and they require a high level of repair and operation. Thus, the machines have low cutting precision, which results in poor quality sawn timber and a large amount of wood waste.

Japanese factories also use band saws to process timber; however the amount of sawn timber that passes quality specifications reaches 98%. In Japan, when the common difference is 1 millimeter (mm), the absolute yield is 68.8%, compared to 50% in China. In the common difference range of 1 mm, the absolute yield percentage is 60.165%. Increasing the common difference by 1 mm, reduces yield by 1.22%. Human error also affects cutting precision.

4.4.2.3 Aggregated statistics of wood residue

Because of the above two items, prestreak out turn in China is relatively high at about 80% and 60%. However, use of sawnwood for wood products is low, at only 50-60%. In the northeastern area, sawnwood use is only is 34.6%. Based on national average prestreak out turn rate of 70% and a 60% sawn timber use rate, the amount of wood residue in China will be 37.04 million m^3, holding 54.7% of the total wood amount. Table 4.6 describes wood residue by region.

The figures given in table 4.6 for sawnwood residue by region are based on real data, including the amount of the exported wood and local prestreak output. In some regions, the sawn timber amounts are more than the local wood output.

Table 4.6 Amount of wood and residue by region

Regions	Wood Residue (10,000 m^3)		
	Prestreak: Sawn timber by 30%	Sawn Timber: Wood products by 40%	Total
Nationwide	20.5248	16.7351	37.2577
Beijing	0.0158	0.0938	0.1096
Tianjin	-	0.0318	0.0318
Hebei	0.1663	0.5424	0.7087
Shanxi	0.1050	0.0300	0.1350
Inner Mongolia	1.5907	0.6818	2.2725
Liaoning	0.4516	1.4307	1.8823
Jilin	1.7737	0.5736	2.3473
Heilongjiang	3.6435	2.3431	5.9866
Shanghai	-	0.0742	0.0720
Jiangsu	0.2309	0.7432	0.9741
Zhejiang	0.7018	0.3393	1.0411
Anhui	0.6681	0.4366	1.1047
Fujian	1.6712	0.8241	2.4953
Jiangxi	0.8073	0.5246	1.3319
Shandong	0.4598	2.8248	3.2846
Henan	0.5777	0.1555	0.7332
Hubei	0.6974	1.7198	2.4172
Hunan	0.9686	0.2269	1.1955
Guangdong	0.9201	1.2071	2.1272
Guangxi	1.2645	0.4000	1.6645
Hainan	0.1341	0.2650	0.3991
Sichuang	1.3934	0.2739	1.6673
Guizhou	0.2316	0.0542	0.2858
Yunnan	1.1726	0.2888	1.4614
Tibet	0.0594	0.0451	0.1045
Shaanxi	0.3171	0.4126	0.7297
Gansu	0.1537	0.0336	0.1873
Qinghai	0.0204	0.0076	0.0280
Ningxia	0.2436	0.0258	0.2694
Xinjiang	0.0849	0.1252	0.2101

4.5 Conclusion

- Because the GOC focuses on forest culture, the afforested areas have increased year after year. However, distribution is still nonhomogenous. It is developed so

that wooded area in the east is greater than in the west, and the south is better than the north.

- Before 1994, the difference between the timber output and sawnwood output was very great. The amount of sawn wood available was about 20% of all lumbered wood, proving a surprising amount of wood was being wasted. The situation did not change until 1995. Since then, the amount of sawn wood has increased to 60%.

- Although the output of wood used as fuel is greater than that in industrial products, this is economically irrational because the value of fuel is less than that of sawn timber, for example.

- To maximize forestry, value, it will be necessary to conserve fiber by cascading the processing. One example is manufacturing sawn timber by means of new technology that produces wood as chips for pulp and paper as a coproduct.

CHAPTER 5 Biomass Resource Database Development in SABRC*

5.1 Goals of the System

The purpose of the Biomass Resource Database System (BRDS) is to provide biomass energy resource and the related data support. It provides researchers and policy decision makers with comprehensive and reliable data.

5.2 Significance of Establishing the System

Biomass is a conventional energy, and people depend on it as a main resource for daily living. In terms of energy capacity, biomass energy ranks just behind coal, oil, and natural gas. Worldwide, biomass is the fourth most consumed energy resource. It plays an important role in the whole energy system.

In China, 80% of the total population lives in rural areas. At present, biomass supplies 38% of the energy in rural areas and 77% of fuel used on farms. As a low-carbon, renewable energy, biomass does not cause serious environmental pollution and it cannot be exhausted. Therefore, it is important to develop biomass energy technologies that promote the construction of China's economy and help meet basic living needs in farm areas. In addition, biomass will mitigate greenhouse gas emissions, which will delay global climate warming and improve the ecological environment.

In the past decade, China has made great progress and advances in biomass energy technologies. However, in general, these technologies are still in the early stages of development, and commercialization and industrialization efforts have progressed slowly. Given this situation, biomass technologies cannot meet the energy demands that have resulted from the nation's rapid economic growth and farmers' improving living standards. One reason is a shortage of study in biomass energy in the soft sciences. It will take a positive effort to investigate, collect, process, and organize theoretical materials and information about available quantities of biomass. The effort will also require establishing a corresponding database management system to analyze biomass resource availability and assess biomass energy. This information can be used to present suggestions for policies and measures in biomass energy development.

* SABRC-- Study on Availability of Biomass Resource in China

5.3 System Analysis

5.3.1 Data indicators system

BRDS centralizes information about biomass energy such as socioeconomic, conventional energy production, and consumption data. It includes the data from the technical paper of this project, which focuses on rural energy. All of this information makes up the data range. The biomass energy data include crop straw and stalk, human and animal excreta, fuelwood, and urban waste. These reflect the quantity of biomass energy and they look at resource availability.

Socioeconomic data include gross national product (GNP) and output values of industry and agriculture, the general population, salaries, financial income and expenditure, price index, and residents' income and expenditures. These reflect rural social and economic development levels, actual rural household incomes and living levels of farmers. They also provide a science-based study showing how biomass energy, conventional energy demand, and rural socio-economic development are related.

Energy production and energy consumption provide complementary information for biomass energy research. The data in the technical paper are divided into straw and stalk, human and animal excreta, and urban waste. These reflect the project's main methods and technical parameters in the research of biomass energy resource availability.

Biomass energy resource data include sown areas, outputs of all crops, and outputs of straw and stalk. Data on human and animal excreta include numbers, scales, and quantities of excreta produced per year. They also describe the status of processing excreta in large and medium-sized livestock farms. The data on urban waste reflect the availability of several metropolitan waste resources and explain the status of processing. Data on of fuelwood resources provides information about woodland areas and the proportion of merchantable trees by wood type.

Case studies based on this research provide confirmation of the data range. The project includes case studies of these regions: Sichuan Province and its two typical counties; Zhejiang Province and its Xiaoshan City and Fuyang City; Shanghai City and its Fengxian County; Shandong Province and its Huantai County and another county. Figure 5.1 illustrates the BERDS indicator system.

The detail information about the biomass resource database indicator system are listed in the following tables (Table 5.1).

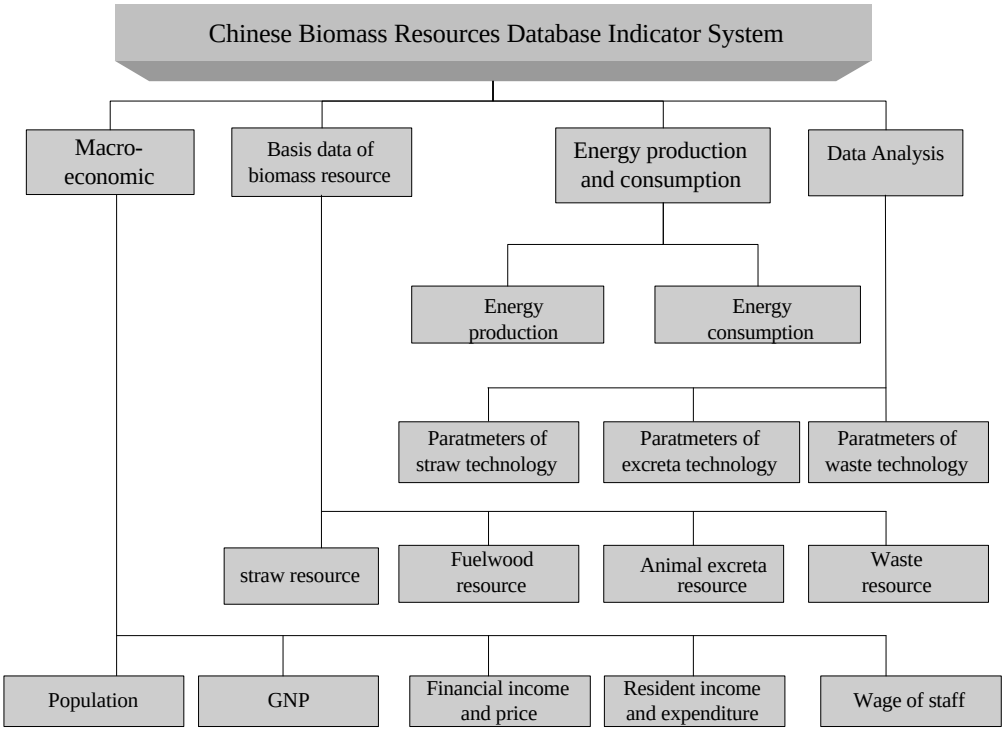


Figure 5.1 Biomass resource database indicators system

Table 5.1 Macroeconomic indicators

I. National economic indicators	GNP(10^8 RMB Yuan)
	GDP(10^8 RMB Yuan)
	Primary Industry
	Secondary Industry
	Industrial
	Construction
	Tertiary
	Transportation, Postal and Telecommunication services
	Domestic Trade
	Per capital GNP
II. Population indicator	Total population at year-end
	Total urban population
	Total rural population
	Employed population
	Total households
	Natural growth rate
	Average persons per household
	Population density

(Continued)

III. Revenue and price index	Revenue indicators	Government revenue from agriculture
		Total expenditures on agriculture
		Expenditure on agriculture administration
		Working capital
		New product promotion funds
		Other
		Ratio of expenditure on agriculture to total
	Price index category	Government expenditure
		National aggregate retail price index
		Residents consumer price index
		Urban residents consumer price index
		Rural resident consumer price index
		Rural residents consumption
		Consumables price index
		Services price index
		Rent price index
		Water and electricity price index
		Transportation fares price index
		Postage price index
		Medicine and medical services price index
		Education fares price index
		Recreation fares price index
		Repair and other services price index
		Repair and other services price index
IV. Staff wage index	Average wage of staff	
	Wage of all staff	
	Wage of staff in state-owned units	
	Wage of staff in collective-owned units	
	Wage of staff in other units	
	Index of average wage of staff	
	Wage of all staff	
	Wage of staff in stated-owned units	
	Wage of staff in collective-owned units	
	Wage of staff in other units	

(Continued)

V. Index of income for household	Index of income for urban household	Beginning cash on hand
		Disposable income
		Cash income
		Real income
		Living income
	Index of expenditure for urban household	Cash expenditure
		Real expenditure
		Nonproductive expenditure
		Productive expenditure
		Credit expenditure
		End cash on hand
		Consumption expenditure
		Food
		Clothing
		Household facilities, articles
		Medicines and medical services
		Traffic and communication
		Cultural, education and recreation articles
		Residence
	Index of income for rural household	Average per capital income
		Average per capital net income
	Index of expenditure for rural household	Average per capital living expenditure
		Food
		Clothing
		Residence
		Fuels
		Household facilities, articles
		Medicines and medical services
		Traffic and communication
		Cultural, education and recreation article
		Average per capita non-commodity expenditure
		Average per capita living expenditure in cash

Table 5.2 Biomass resource indicators

I. Indicators of straw and stalk resource	Sown areas and crop output indicator	Grain crops
		Rice
		Wheat
		Corn
		Soybeans
		Tubers
		Economic crops
		Cotton
		Oil bearing
		Peanuts
		Coleseed
		Hemp
		Jute and amber hemp
		Sugar
		Sugarcane
		Beetroots
		Tabacco
		Flue-cured tobacco
		Other
		Vegetables
		Green manure
		Tea plantations at year-end
II. Forestry resource indicators	Forestry area	Forestry land use area
		1.area with woods
		2.land of young woods
		3.land of shrub
		4.land of thinning woods
		5.land of nursery garden
		6.land without woods
		in which: fell and barren land suitable for afforestation
		Nonagricultural land area
		in whichcultivated area
		growing stock
		in whichstock in young woods
		stock in adult or over maturity woods
		in the growing stock: man-made woods
		Accumulated afforestation areas after PRC founded
		Existing man-made woods areas
		Accumulated man-made woods areas cut
		as percentage of the forestry area
		Unit stock in land with woods
		Ratio of man-made woods stock to total growing stock
		Average conserved rate of man-made woods
		Average per capital area of land with woods Average per capital woods stock

(Continued)

III. Animal excreta resource indicators	Number of the cattle and buffalo
	Number of the milk cows
	Number of live hogs per year
	Number of live hogs at year-end
	Number of husbandry at year-end
IV. Urban waste resource indicators	Daily urban waste water treated capacity
	Sanitary waste removal
	Human excreta removal

Table 5.3 Energy production and consumption and data analysis

I. Energy production indicators	Total energy production (TEP)
	Ratio of raw coal to TEP
	Ratio of crude oil to TEP
	Ratio of natural gas to TEP
	Ratio of hydro-power to TEP
II. Energy consumption indicators	Total consumption and end-use
	Coal (10^4 ton)
	Refined coal (10^4 ton)
	Other washed coal (10^4 ton)
	Coke coal (10^4 ton)
	Crude oil (10^4 ton)
	Fuel oil (10^4 ton)
	Gasoline (10^4 ton)
	Kerosene (10^4 ton)
	Diesel oil (10^4 ton)
	LPG (10^4 ton)
	Oil refinery dry gas (10^4 ton)
	Natural gas (10^4 m^3)
	Coke-oven gas (10^4 m^3)
	Heating power (10^{10}kJ)
	Electric power (10^8kWh)
III. Energy balance indicators	Total energy available for consumption
	Primary energy output
	Imports
	Exports
	Stock changes
	Consumed in transformation input/output
	electricity
	heating
	washed coal
	coking

(Continued)

	rendering
	gas works
	Losses
	in which: T& D loss
	Final consumption
	Materials production sectors
	Farming, Forestry, Animal and husbandry, Fishery
	Industry
	Construction
	Transportation, postal and telecommunications services
	Commerce
	Nonmaterial production sectors
	Residential consumption
	Urban
	Rural
	Balance
IV. Data analysis	

5.3.2 Data range

The database provides three levels of information: national, provincial, and prefectural. Data at each level refer to gross values of one item in past years. Within these, socioeconomic and biomass energy resource data are further divided into three levels; urban waste data combines information from several typical metro-politan areas; and livestock excreta data includes large and medium-sized livestock farms in every province. The data in the technical paper includes only the para-meters for which resource quantities were calculated. This is illustrated as Figure 5.2.

5.4 System Design

5.4.1 The option of developing method

The features of BERDS allow full use of existing functions in the software and can quickly generate system results. First, the system is suited to special projects and adopts small and fine system analysis and design. Second, this system development can go ahead of other jobs to provide researchers or policy decision-makers with comprehensive and reliable data. Thus, the system development adopts a convenient and express method. Third, users of this system emphasized the need for good data file conversion to make the data usable in another software environment. After

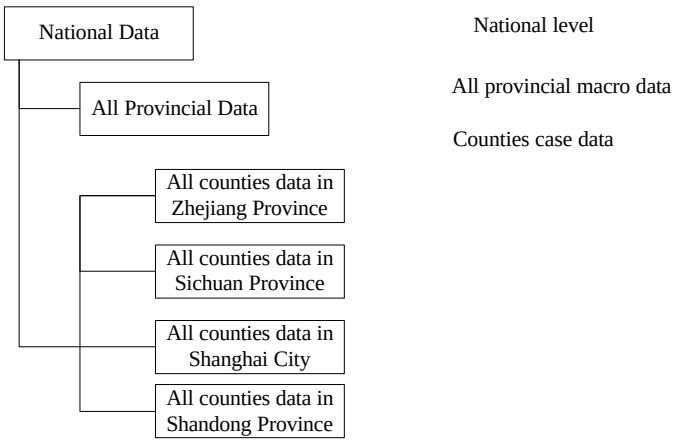


Figure 5.2 Data range of database and its hierarchical diagrammatic sketch

comparing the features of many software applications, Microsoft Excel seems to be the most suitable and competent for this system development.

5.4.2 Database structure design

The database structure is based on classification within a data indicator system. The system creates many sub-databases and stores data by type using the rule of "one thing, one place." In Excel′s data file management mode, the sub-databases can be stored in specialized worksheets. The following Table 5.4 shows how data is stored.

5.4.3 System menu design

The system menu is convenient to use and incorporates macros in Excel. The related macros are shown in the models below. Menu options include "Macro-economics", "Biomass Energy Resource", "Energy Production and Consumption", "Technical Parameters", and "Quit System". Other functions such as file manage-ment, editing, and worksheets input and output are the same as in the Excel menu.

5.4.4 System function

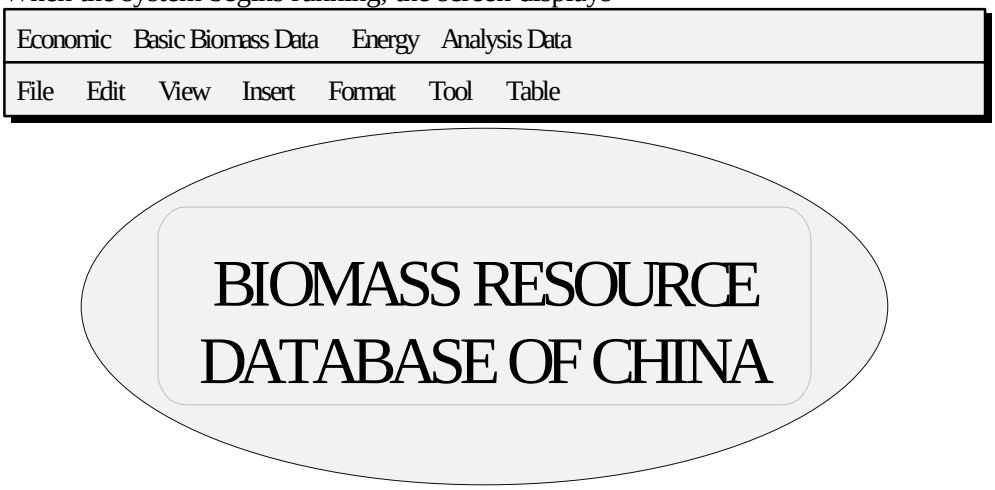
BERDS designs convenient, visual data inquiries. Users can quickly find data by selecting the system menu options. The system retains Excel functions to edit data, save files, print reports, input and output figures, and convert files. It also uses Excel functions to perform data statistics analysis, sorting, and filtering. This development strategy and the technical process can quickly develop this system. By making use of existing development software, BERDS produces twice the results with half the effort.

Table 5.4 Meanings corresponding to the sheets name in the database

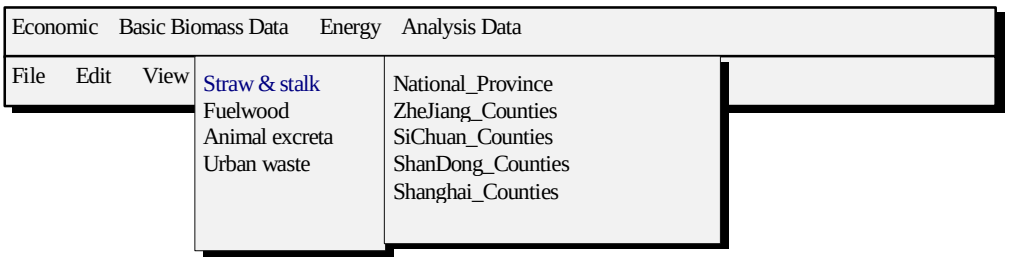
Indicators type	Data contents	Sheet name
Population and its constituent	National and all provincial data	sheet 5
	Shandong Province and its all counties′ data	sheet 9
	Sichuan Province and its all counties′ data	sheet 36
	Zhejiang Province and its all counties′ data	sheet 28
	Shanghai City and its all counties′ data	sheet 14
Wage of staff	National and all provincial data	sheet 8
	Sichuan Province and its all counties′ data	sheet 31
	Zhejiang Province and its all counties′ data	sheet 27
	Shanghai City and its all counties′ data	sheet 15
GNP	National and all provincial data	sheet 4
	Shandong Province and its all counties′ data	sheet 35
	Sichuan Province and its all counties′ data	sheet 34
	Zhejiang Province and its all counties′ data	sheet 25
	Shanghai City and its all counties′ data	sheet 13
Revenue	National and all provincial data	Sheet 6
	Shandong Province and its all counties′ data	sheet 11
	Zhejiang Province and its all counties′ data	sheet 26
	Shanghai City and its all counties′ data	sheet 19
Residential expenditure and income	National and all provincial data	sheet 2
	Shandong Province and its all counties′ data	sheet 12
	Sichuan Province and its all counties′ data	sheet 42
	Zhejiang Province and its all counties′ data	sheet 24
	Shanghai City and its all counties′ data	sheet 20
Straw and stalk resource	National and all provincial data	sheet 3
	Shandong Province and its all counties′ data	sheet 10
	Sichuan Province and its all counties′ data	sheet 32
	Zhejiang Province and its all counties′ data	sheet 22
	Shanghai City and its all counties′ data	sheet 21
Forestry resource	National and all provincial data	sheet 30
Livestock excreta resource	National and all provincial data	sheet 44
	Shandong Province and its all counties′ data	sheet 33
	Zhejiang Province and its all counties′ data	sheet 23
	Shanghai City and its all counties′ data	sheet 16
Urban waste resource	National and all provincial data	sheet 47
	Zhejiang Province and its all counties′ data	sheet 48
	Shanghai City and its all counties′ data	sheet 49
Energy output	National and all provincial data	sheet 40
Energy consumption (comprehensive energy balance sheet)	National and all provincial data	sheet 17
	Sichuan Province and its all counties′ data	sheet 41
	Zhejiang Province and its all counties′ data	sheet 29
	Shanghai City and its all counties′ data	sheet 18

5.5 System Guidelines

When the system begins running, the screen displays

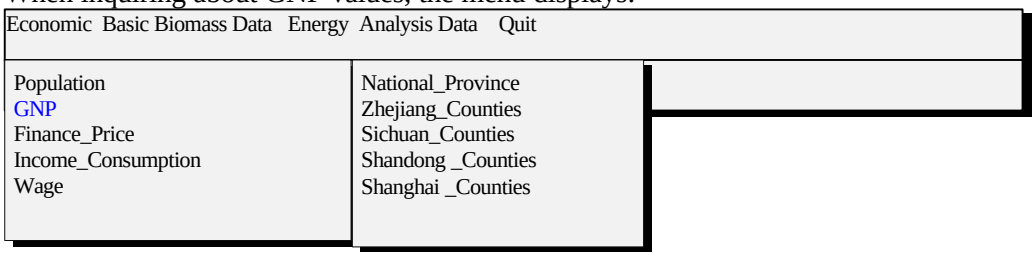


Selecting a menu displays its contents:



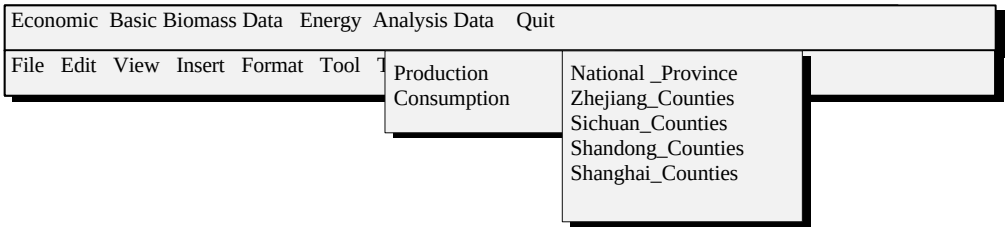
To quit the inquiry and return to Excel for data analysis**,** the user selects "Return to Excel" in the menu. In Excel, the user can select the worksheets and edit data, create figures, compile statistics, and print documents .

When inquiring about GNP values, the menu displays:



When the user inquires Energy Production and Consumption value, the menu would

be as the following.



When inquiring about Straw and Stalk resource value, the menu displays:hen the user wants to quit the system, he can select Close in item File in the menu.

5.6 System Environment

5.6.1 System

This database includes 50 worksheets, and about 5000 records with 200 data indices. And millions data are calculated. The total data storage capacity reaches up to about 6M. This system can be run with high safty, and the calculation is accurate with rapid response. Moreover, the system is easy to maintained.

5.6.2 Required software and hardware

5.6.2.1 Hardware

(1) Computer: 486 or better with 4 M memory or more
at least one 3 inch floppy disk drive and 120 M or more harddisk.
(2) Monitor: VGA
(3) Printer: all kinds printer

5.6.2.2 Software

(1) Operation System: Windows 3.1 or Windows 95, plus Chinese system such as Chinese Star or Richwin.
(2) Excel 5.0

CHAPTER 6 Research on the Availability of Biomass Resource in Sichuan Province

6.1 Brief Introduction

6.1.1 Socio-economic and environmental background

Sichuan Province is located in the southwest China and the upper reaches of Yangtze River, between the east longtitude of 97°26′ and 110°19′, and north altitude of 26°03′ and 34°19′. It is the southwest center of economic, communication and transportation. It covers an area of 567,600 square kilometers (km^2) with forest coverage of 20.4%. Its west is tableland and the east is basin. Sichuan Province is also the center of economy, traffic, and communication in the southwest China. The climate in the east part of Sichuan is generally subtropical with an average annual rainfall above 1,000 mm and the west is cold plateau climate with an annual rainfall below 600 mm. Sichuan flows with rich water power resources, and the hydro-reserves total 150 million kilowatts (kW), of the area that has been explored has reached 92 million kW. The province is comprised of 6 prefectures, 3 autonomous prefectures, and 14 cities of prefecture-level. Until 1995, the population in the province was 111.629 million with 31.954 million households in total. Of that total, 92.717 million people live in rural area people with 26.35 million households engaging in agriculture production.

Table 6.1 Basic land and population information of Sichuan Province and its partial regions

	Total Area (million km^2)	Total population (millions)	Rural population (millions)	Total households (millions)	Rural households (millions)
Sichuan	0.5676	111.629	92.717	31.954	26.35
Mianyang City	0.020249	5.031	4.203	1.481	1.257
Mianzhu County	0.001246	0.5	0.4275	0.158	0.1357

Sichuan has a vast area, a multi-type climate of vertical change, and rich natural resources of light, thermal, water, soil, organisms, and minerals. These advantages have laid a sound material foundation for the development of the economy. Sichuan is a province of significance to the agriculture production of China and abounds in grain, oil, and living pigs. Total grain output ranks first in China, living pig output makes up 20%. In 1995, there was a total output value of national production of 311,123 million Yuan in the province. Agriculture accounted for 28.38%, industry-

Figure 6.1 Sichuan administrative region

41.98%, the tertiary industry-29.64%. With the constant development of rural economy, farmers' income goes up by 6% each year. Rural power consumption grows by 10% annually and farmers' living standard has a remarkable improvement. The production condition of agriculture is better than before. Total power of agricultural machinery in the province has climbed to 1.2631 million kW and the annual growth rate goes up by 7%. This growing trend will be maintained following the further development of economy. Though most farmers have rid themselves of poverty, only a few have become rich. A few still live in poverty until now.

Table 6.2 Economic status of Sichuan and partial regions in 1995

	GDP* (billion Yuan)	Revenue (billion Yuan)	Per capita income of workers (Yuan)	Per capita net income of farmers (Yuan)
Sichuan	311.123	13.599	3,312.54	1,040.33
Mianyang City	16.352	0.731	4,149	1,120
Mianzhu County	2.85	0.164	5,200	1,500

With the expansion of economy, people's demand for living improvement, and the fast development of industrial production have posed a pressure to environment. The environment pollution has become an important factor that inhibits the further development of the province's economy to some extent. Vegetation has been destroyed and soil erosion has becomes serious. Owing to the massive population,

the high index of land cultivation, and over-cultivation of portions of land. The large quantity of firewood that is used for cooking has constituted a great damage to forests and has aggravated soil erosion. The area of soil erosion of the province dropped from 249,000 km^2 in 1985 to 178,000 km^2 in 1995. The situation is still very grave. Water and atmosphere pollution have become critical. Eighty percent of waters in the province have been polluted to various degrees and the atmospheric quality has experienced widespread decline. The province has adopted measures to control environmental pollution. Great achievements has been made: 326 smoke and dust control areas have been set up, 205 environment qualification districts have been completed, the control rate for industrial waste gas is up to 74%, wastewater is 48.6%, and overall control rate for solid wastes is 53.2%. In a word, the environment of Sichuan Province tolerates no optimism.

6.1.2 Characteristics of energy production, energy supply and consumption

6.1.2.1 Total amount of energy production and energy consumption keeps a fundamental balance; however, a great difference among the variety exists

In 1995, the total amount of commercial energy production in the province was 74.955 million tons of standard coal while that of energy consumption was 76.629 million tons of standard coal. Besides a little amount of coal and natural gas being exported to other provinces, crude oil, and electricity need to be import. Crude oil especially, 74.57% of it must be imported. In short, Sichuan Province is an energy import province.

6.1.2.2 Composition of energy consumption

The composition of energy consumption in Sichuan Province has undergone great changes in recent years, and the continuous growth in commercial energy consumption and the fast expansion of high-grade energy consumption such as electricity and oil are the main reasons. Of the composition of energy consumption, domestic consumption is 40.56 million tons of standard coal, accounting for 43.55% of the total energy consumption; energy consumption for agriculture makes up 0.6% of total energy consumption; energy consumption for industrial production accounts for 51.15%, energy consumption of the third industrials like traffic makes up 4.68%. The figures in Table 6.3 show that energy consumption of industrial and rural areas are the key factors which account for 90.34% of the total amount. From the viewpoint of energy consumption variety, commercial energy occupies the lead position and accounts for 65.39%, and biomass accounts for 34.61%. So far as area is concerned, the rural area is the main area for energy consumption, equaling 51.3638 million tons and accounting for 55.16% of the total amount. Rural domestic energy consumption is 36.497 million tons of standard coal. Energy consumption for agricultural production is 0.5715 million ton of standard coal, for township industry is 13.3367 million tons, other enterprises in the township is 0.9587 million ton of standard coal.

Table 6. 3 Total amount of commercial energy production, consumption, and composition of Sichuan in 1995 (10^6 TCE*)

	Total amount	Coal	Crude oil	Natural gas	Hydro-electricity
Energy production	74.955	62.8872	0.2249	9.2944	2.4585
Ratio of composition	100	83.9	0.3	12.4	3.4
Energy consumption	76.629	61.4565	3.6016	8.9656	2.6053
Ratio of composition	100	80.2	4.7	11.7	3.4

*TCE = ton coal equivalence

Table 6.4 Composition of energy consumption of Sichuan in 1995

Variety	Electricity	Coal	Oil	Natural Gas	Fuelwood	Stalks	Biogas	Total
Unit	PWh	10^6TCE	10^6t	10^8m^3	10^6TCE	10^6TCE	10^8 m^3	10^6TCE
Rural life	19.32	6.4548	0.045	0.11	18.807	10.456	6.5	36.497
Town life	33.07	0.6007	0.0035	25.1	0.0078	0.024	0.1	4.063
Agricultural production	20.44	0.025	0.1746	0.38				0.5715
Industrial production	326.1	32.456	0.9213	63.14	0.038	2.235		47.631
Other industrials	41.62	0.59	1.1661	11.67	0.012	0.176		4.3575
Total	440.55	40.1265	2.3105	100.4	18.865	12.891	6.6	
10^6 TCE	5.4143	40.1265	3.3040	12.04.8	18.865	12.891	0.4712	93.12

Note: The figure of coal, oil and natural gas in the table have detected the loss that converts to electricity and the loss during transport and processing.

6.1.2.3 Energy consumption in rural area

Domestic energy consumption accounts for 71.06% of the total amount in rural areas. Biomass consumption constitutes 62.67% of the total energy consumption in rural areas, of the rural domestic energy consumption in particular, biomass accounts for 81.45%.

Table 6.5 The trend of rural energy consumption in Sichuan Province

	1985	1990	1992	1995
Total amount (10^6 TCE)	47.0079	48.3568	42.7206	36.497
Electricity (PWh)	7.33	10.58	13.96	19.32
Coal (10^6 TCE)	9.2943	10.8289	9.4839	6.4548
Oil (10^6 t)	0.1145	0.0989	0.0675	0.045
Natural gas (10^8 m^3)	0	0	0.05	0.11
Biomass (10^6 TCE)	37.1957	37.2565	32.9626	29.727

In the last ten years, there has appeared a remarkable change in rural energy consumption. Rural domestic energy consumption reached the highest level in 1990, of 48.3568 million tons of standard coal, then domestic energy consumption decreased steadily. This can be explained by many reasons. First, the evolution of rural energy conservation and the implementation of firewood-saving stoves. There was a remarkable improvement in the overall thermal efficiency of energy consumption for cooking, the thermal efficiency went up from 10.74% in 1985 to 19.88% in 1995. Consequently, with the steady growth of effective energy for rural life, the amount of energy consumption decreased steadily. The second reason for the decline in domestic energy consumption is that energy used in cooking pig feed has reduced significantly in recent years by popularizing the way of using uncooked feed. Third, third, the consumption ratio of high-quality energy that has a higher thermal efficiency than coal, firewood, and stalks is gradually increasing in rural areas. Fourth; large quantities of surplus manpower in Sichuan rural areas have shifted to cities and the other provinces of the country causing a decrease in actual population, therefore, the amount of energy consumption reduced correspondingly. However, it should be understood that firewood-saving and coal-saving stoves, and the adoption of uncooked pig feed have reached their limits and their further expansion appears unlikely, therefore, the amount of rural domestic energy consumption will gradually slow down yet, there is the possibility that the amount of rural domestic energy consumption will grow along with the development of economy.

Despite the variety type of rural domestic energy consumption, electricity consumption keeps a constant growth. The amount of domestic consumption of oils keeps dropping, electricity replaces oils, and the rural electricity net continually improves the rural power supply. After 1990, consumption of coal and oil, They declined because the need for rural domestic energy consumption reduced, the utilization of stalks and firewood lagged behind, and farmers were not willing to use low-grade energy because they had a better life-style than before. This trend is an inevitable outcome of economic development and will maintain for a long period of time.

Prices of various energy varieties have certain influence on the above transition. Fuel expense per capita in Sichuan's rural areas had a steady growth annually, and a large increase occurred in 1993 and 1994 after a long-term stability of the ratio in the living expenses per capita. These two years fully illustrated the relationship of the inverse ratio between price increase and consumption as compared with the reduction of rural domestic energy consumption of the same two years. It should be pointed out that the increase in energy consumption expense also contains the factor for the growth of high-grade energy consumption.

Table 6.6 Relationship between living expense and energy expense per capita in Sichuan' rural areas (Yuan)

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Annual energy expense	15.43	14.71	15.32	20.16	21.02	25.30	25.19	25.63	41.91	82.75
Annual living expense	276.3	310.9	348.3	426.5	473.6	509.2	552.4	569.5	647.4	904.3
Ratio (%)	5.58	4.73	4.40	4.73	4.44	4.97	4.56	4.50	6.47	9.15

As far as the present energy consumption in Sichuan Province, the price is the main factor inhibiting farmers in utilizing the high-grade commercial energy such as liquified gas and other new type fuels. The present income of farmers is fairly low and they feel it is a high consumption to pay more for this kind of energy. But the farmers have higher incomes near the suburbs of cities and the utilization rate of liquified gas grows fast. This shows that the utilization ratio of high-grade energy will become greater as farmers' income increases.

6.1.2.4 Growth in rural production consumption

The amount of energy production consumption in Sichuan's rural areas experienced a growth spurt in 1990, because of the increase of energy consumption in township enterprises, while energy consumption for agriculture production stayed at a constant level.

In view of township enterprise, Sichuan's township enterprise developed fairly fast, production value increased remarkably and energy consumption increased after 1990. Energy consumption for township enterprises in 1985 was 9.1191 million tons of standard coal, 1990-9.8756 million tons, and 1995-14.2954 million tons. Coal is the fuel consumed and accounts for 80% of the total consumption. Other varieties of fuel of energy did not vary greatly.

Regarding agricultural production, the amount of energy consumption for agri-cultural production in 1985 was 0.509 million tons of standard coal, in 1995-0.5715 million tons of standard coal. It only increased 0.0625 million tons of standard coal in the last ten years because Sichuan Province has a large area of hilly land and mountains, therefore it is slow in the development of agriculture mechanization.

Energy consumption for agricultural production is not related to energy price and its varied composition primarily depends on requirement.

6.2 Distribution of Biomass Resources

6.2.1 Variety

6.2.1.1 Straw and stalk crops

The Sichuan province is a significant contributor to the agricultural production of China. Its main crops are rice, wheat, and corn, therefore, it is full of straw resources.

Table 6.7 Crop straw resource in Sichuan in 1995

	Rice	Wheat	Corn	Bean	Rape	Ramie	Sugarcane	Cotton	Total
Growing area (10^6 ha)	2.98	2.31	1.71	0.57	0.93	0.057	0.035	0.13	8.73
Yield (10^6 t)	22.06	8.40	6.65	0.93	1.70	0.084	1.802	0.07	41.76
Ratio of grain & straw	1	1	2	1.5	2	2.5	0.1	3	
Total amount of straw (10^6 t)	22.06	8.70	13.30	1.49	3.41	0.21	0.18	0.20	49.25

6.2.1.2 Utilization Status of Straw and Stalk

At the beginning of 1996, the Rural Energy Office of Sichuan Province performed an overall survey of the utilization status of straw resources in the province to work out a rural energy program. The main uses of straw are: fuel, animal feed, raw materials for industry, and organic manure. The office also calculated the ratios of the different uses of straw and based on the ratio, calculated the distribution of variety and quantity of straw for the whole province as shown in the following table.

Table 6.8 Statistical table of the crop usage in Sichuan Province (million tons)

Straw	Ratio	Rice	Wheat	Corn	Bean	Rape	Ramie	Sugarcane	Cotton	Total
Total quantity	100	22.06	8.399	13.30	1.49	3.41	0.21	0.18	0.201	49.25
Feed	17.8	6.50	-	2.20	0.05	-	-	-	0.05	8.80
Back to the field	9.7	2.40	1.60	0.40	-	0.04	-	-	-	4.80
Paper-making	6.5	0.40	2.80	-	-	-	-	-	-	3.20
Others	9.5	0.80	2.35	1.20	-	0.28	0.04	-	-	4.67
Fuel	56.5	11.96	1.649	9.502	1.44	2.73	0.17	0.18	0.151	27.78

The crop-straw used for energy has a maximum ratio and accounts for 56.5%, crop-straw which is indirectly utilized as organic manure by first used as animal feed then using the animal waste in the field. Crop-straw used directly back to the field accounts for 27.5%, while industrial use only makes up 6.5%. Taking a long view that the gravity of energy consumption is still great, this gravity is reasonable if it can be gradually controlled in the range of 40%. A total number of 16.5 million households in the province have firewood and coal-saving stoves at present. The

overall thermal efficiency for cooking in rural areas is 21.9%, therefore, there still exists a certain potentiality of energy conservation.

6.2.2 Poultry and livestock excrement

6.2.2.1 Total quantity

A great quantity of poultry and livestock excrement exists in the province, however it is rarely utilized except for the pastoral areas in Ganzi and Aba Autonomous Prefectures that are used to burning the dry excrement. Biogas construction in Sichuan has experienced development, currently, a number of 2.17 million household biogas digesters have been set up with an annual gas production of 0.65 billion cubic meters. The comprehensive utilization of excrement resource can both develop energy efficiency and manure efficiency. It is the best way for utilizing excrement resource.

Table 6.9 Statistics of poultry and livestock excrement in Sichuan (1995)

	Cow	Pig	Sheep	Poultry	Rabbit	Horse, donkey
Quantity (million heads)	11.159	70.909	12.055	248.647	19.563	0.70
Quantity of excreta (kg/heads)	1,300	300	75	15	35	1,350
Amount of excrement (million tons)	14.507	21.273	0.904	3.73	0.685	0.945
Collection coefficient	0.6	1	0.6	0.6	1	0.6
Developable amount (million tons)	8.704	21.273	0.542	2.238	0.685	0.567
In terms of standard coal (million tons)	4.10	9.126	0.287	0.96	0.362	0.30

6.2.2.2 Distribution of breeding farms of large and medium size

Decentralized breeding is the way of animal husbandry in Sichuan except for milk farms that still keep commercialized production. Agriculture and animal husbandry make up 95% of the total production of the province. Pig farms of big and medium size that had been constructed relying on government or policy support were transformed or closed successively because of many reasons. Only a few strong households of pig-breeding are engaging in commercialized production, however, the annual slaughter rate of living pigs is within the range of 200 to 300 head, yet the production is not stable. At present, 132 farms only raise about 3,400 pigs in the province. There are 156 cow farms of big and medium size in the province currently, with a quantity of 0.178 million heads of cow anticipated by the end of the year, among there are 0.018 million heads of milk cow. Big and medium size cities as well as the developed counties raise milk cows in pens and are responsible for supplying fresh milk for the local residents. Milk production benefits little and has been maintaining production by relying on the subsidies from government. In recent years, milk cow production has embarked in market development by means of raising the milk price, however, it still faces difficulties of low economic efficiency. It is hard to expand the scale of breeding.

In poultry breeding, they are over 400 chicken farms of big and small scale , with 30 million chickens in total. Most of the chicken farms are distributed throughout suburbs of big and medium cities. The economic benefit of these farms is fairly good as they mainly produce eggs and meat chickens. Individual households who have economic strength raise ducks and geese by water breeding and seldom shut them in pens except a few seed-egg supplying households.

6.2.2.3 Treatment situation of poultry and animal excrement for big and medium breeding farms

The majority of poultry and animal excrement has not been treated effectively in Sichuan's big and medium breeding farms. It is directly put back to the fields of the neighboring households or farms for agriculture production. Only a part of it is directly discharged to the surrounding waters. Only the poultry and animal excrement discharged from the six breeding farms in the province has been treated innocuously through biogas fermentation. In light of environmental influence, the direct discharge of poultry and animal excrement to the surrounding waters has seriously polluted the environment, residents living there are complaining about the pollution.

Departments of environment protection issue orders to ban the direct discharge. The pollution to the environment will reduce if excrement is used for agriculture production, however, the waste will overflow and pollute the surroundings during the process of composting, or during the seasons the farmers do not apply fertilizer. Many years of practice has shown that poultry and animal excrement that has been treated by biogas digesters can reach the standard of innocuity. Poultry and animal excrement can be kept in the digester for quite a period of time by utilizing the digester space to avoid overflow, therefore, it is quite advantageous in improving the environment and the hygienic conditions. Biogas fertilizer (residue from biogas digesters) has greatly improved in its efficiency and it can be used comprehensively to promote agriculture production. A lot of breeding farms of big and medium size have understood the significance of treating excrement by biogas digesters, however, most of them have no money to set up biogas projects because of their poor economic situation. It is very difficult for these farms to obtain a loan to construct biogas projects because the direct economic benefit of biogas projects is very low. It is hoped that government or international organizations provide financial support for these farms.

In light of big and medium breeding farms with biogas projects constructed, the operation status is not good and their main troubles are as follows:

Table 6.10 Status of biogas projects of big and medium breeding farms in Sichuan Province

Names and variety milk cow	Annual breeding quantity (1,000 heads)	Total volume of biogas project (1,000 m^3)	Operation status and usage
Breeding Stock Farm, Mianyang City	0.15	0.9	for civil use
Breeding Farm of Agr. Res. Institute, Mianyang City	0.12	0.93	for civil use
Breeding Stock Farm, Neijiang City	0.1	0.6	for civil use
Dongshan Farm, Deyang City	0.13/pig-0.6	0.5	out of operation
Fenghuangshan Farm, Chengdu City	0.25	0.8	for civil use
Shuangtu Chicken Farm, Shuangliu County	Chicken-100/pig-0.2	0.3	hatching chickens

a. These biogas projects were set up very early and most of them were completed in the middle and late period of 1980s. They have no facilities for comprehen-sive utilization of biogas and fermentation residues. Shuangtu Chicken Farm at Shuangliu County is the exception. Economic benefit is rather poor as a result, the initiative of management for the breeding farms is affected. There exists the circumstances of poor management and those unwilling to pay for maintenance of biogas projects. Shuangtu Chicken Farm has received good economic benefits by using biogas to hatch chickens. The Director of the farm looks on biogas projects as an important facility to earn money, consequently, the management initiative is very high and the biogas project is operating well.

b. Biogas produced from biogas projects is manufactured by staff members of the farm for no pay, the farm has received little or no return biogas projects. Worst of all, the cost for management and maintenance is not sufficient. Because the likelihood of recovery of the investment is nil, the management of biogas projects are not implemented effectively.

c. Most of these biogas projects get financial support from government, non-enterprise investment, or enterprise pay which sparse. Enterprises seldom care about biogas projects.

d. Economic conditions of these farms are very poor and there are unable to construct complete projects or carry out careful management.

e. Management personnel quality is poor. Often they have no experience in management, therefore, the normal operation of biogas projects is affected.

6.2.3 Sugarcane bagasse

Total production of sugarcane of the province in 1995 is 1.6503 million tons. Among Panzhihua City, Neijiang City, Leshan City, and Yibin Prefecture, each has a production over 0.1 million tons. The province has 34 sugar refineries with a sugarcane production of 0.1131 million tons, sugarcane bagasse, about 0.5776 million tons annually. Reasonable utilization of sugarcane bagasse has been effectively implemented because bagasse is concentrated at sugar refineries. Of the 34 sugar refineries in the province, 33 of them use bagasse to make paper, this amount makes up 97% of consumption with an approximate quantity of 0.56 million tons. The remaining bagasse is used for fuel by farmers.

6.2.4 Solid waste in cities and towns

6.2.4.1 Distribution

A complete statistical analysis has not been conducted for the quantity and composition of the solid rubbish in cities of the province as a result of different ways of collection and treatment in various areas. We made a typical case study on Mianyang City, the conclusion is as follows:

a. Solid rubbish in cities shows a growing trend along with the development the economy;

b. As the economic condition of the residents is different, quantity, and composition of rubbish differs also;

c. Because the structure of residents' domestic energy consumption is different, the quantity of solid rubbish differs a great deal.

The following is the survey results of the solid rubbish of Mianyang City and the prediction conducted by personnel of Environment Protection. Tables 6.11 and Table 6.12 testify to the above conclusions.

6.2.4.2 Treatment situation

Concentrated composting and filling are the main ways to treat rubbish in Sichuan Province at present and they have reduced the quantity of rubbish in the downtown to a great extent. With the growth of rubbish, the above treating methods have caused serious pollution and social problems. In regards to environment, rubbish has brought a second pollution factor to the site of refuse. The ground water can not drunk be within a radius of 2 km around the center of the refuse site. Crops that grow around the site harm humans because flies and mosquitoes propagate at the refuse site. As far as safety, the large quantity of biogas produced from the rubbish

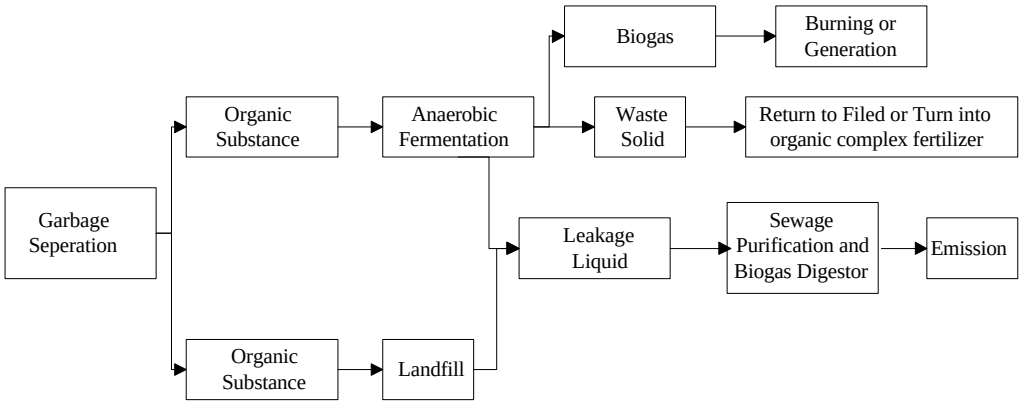
Table 6.11 Statistics of solid rubbish in the downtown of Mianyang City (excluding industrial waste)

	1990	1995	2000
Population (1,000 people)	301	336	356
Income of living expenses per capita for urban residents (Yuan)	1,800	3,550	6,000
Total quantity of rubbish (1,000 ton)	73	156.3	220-250
Total volume of rubbish (1,000 m^3)	121	256.2	360-410
Daily production of rubbish (ton)	200	428	603-686
Rubbish amount per capita (kg/person/year)	242	465	618-702

Table 6.12 Composition of domestic rubbish at different districts in Mianyang City (1995)

Composition	Organic matter (%)					Inorganic matter (%)				
District	Plant content	Animal content	Paper content	Plastics content	Total content	Brick stone content	Lime content	Cinder content	Metal content	Total content
Gas as fuel	63.02	6.89	2.90	6.6	79.41	1.76	5.96	11.69	1.18	20.59
Coal as fuel	15.76	1.04	0.29	2.8	19.89	2.76	66.16	10.66	0.53	80.11
Main road	79.77	0.65	4.12	0.3	84.84	1.45	5.76	5.50	2.45	15.16
Commercial street	83.08	1.98	2.47	3.8	91.33	1.76	6.41	0.1	0.4	8.67

easily leads to explosion. One ton of rubbish composting can generate 30 m^3 biogas. Our county has experienced quite a few explosions at refuse sites. These cases have severely affected the production and living of nearby residents and have caused a lot of social problems.



At present, some areas in our province are actively trying to find ways for comprehensive utilization of rubbish resources. Sieving rubbish, filling inorganic matters, and producing compound fertilizer are the main methods adopted. There exists the phenomena of incomplete technology, high cost of operation, strong labor

intensity of personnel, and poor environmental and hygienic conditions, consequently, the normal operation of refuse site is negatively influenced.

6.3 Economic and Scale Analysis of Straw Resource Collection

6.3.1 Collection range

Different biomass resources have different collection ways, therefore, the collection radius differs a great deal. Since the responsible policy was carried out in rural areas, each rural household has collected the straw in its responsible field with a distance of not more than one kilometer. Up to now, Sichuan Province has no cases of purchased straw for energy purpose on file. As far as the situation of paper-making enterprises (for purchasing straws as the raw materials), the distance of flatlands is not more than 8 km, the hilly land-5 km, the mountains-3 km, otherwise, the rural households are not willing to sell straw because the transport cost is too high. Of course, it is related with the economic status of the local farmers. Areas where economic conditions are poor, the collection radius is greater than that of well-to-do areas, because rural households of poor economic condition need the income of purchasing straw more than the well-to-do households.

6.3.2 Density of distribution

The cultivated land in Sichuan in 1995 was 6.2144 million hectares with an annual straw production of 49.247 million tons. The average production per hectare was 7.92 tons. Straw production at the flatlands and the southeast part of Sichuan is higher than that in the mountains and the west part of Sichuan because the growth of crops depends on climate conditions. As viewed from density of distribution, the flatlands are fit for the collection of straw.

6.3.3 Collection cost

The price of straw in Sichuan Province is affected by the purchasing price of industrial raw materials. The purchasing price of wheat-stalk is 0.15-0.20 Yuan/kg, the price of rice-straw and corn-stalk should be less than that of wheat-stalk. In fact, straw of other agriculture crops are never sold at the market except wheat-stalk.

6.3.4 Location

The application of gasification technology of straw has great difficulties in Sichuan. First, there exists a great difference in the way of living for rural residents between Sichuan and the north part of China, it is inconvenient to install pipes because of the scattered living of rural residents in Sichuan. Second, the storing of straw requires special houses because Sichuan is wet and rainy and the concentrated store of straws

is expensive. Third, biogas is developing smoothly in Sichuan's rural areas, most farmers have a good understanding of biogas, therefore, farmers are very active in developing this technology. Fourth, the cost of straw gasification is expensive and has prevented rural households from participating at present. Rural energy depart-ments in Sichuan have carried out a feasible investigation at Mianzhu County and their conclusion is on the application of straw gasification technology is not suited to Sichuan.

Based on the survey, there still exist problems for the technology of solidification (carbonization and shaping) of straw due to the high processing cost. It has been difficult to extend this technology. Two fundamental conditions should be provided if it is planned to extend this technology: first, price of end products for energy should be the same as or lower than that of briquette at local areas; second, adaptable stoves in convenient operation should be provided. It is very difficult to realize the first condition because coal prices are not expensive in rural areas.

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CHAPTER 7 Research on the Availbility of Biomass Resource in Zhejiang Province

7.1 Introduction

7.1.1 Socio-economic and environmental basic features of protection

Zhejiang Province lies in east China administrating upon 87 counties and cities. By the end of 1996, the population was 43.412 million, a population density of 426 people per square kilometer (km^2). It is well known that in Zhejiang Province, the percentage of mountains, waters, and farmland are 70%, 10%, and 20%, respectively. The total land area of the whole province is 101,800 km^2, in which, mountain area, 70.4%; plains area, 23.2%; rivers and waters, 6.4%. The annual average precipitation is 1,485.4 mm, total annual total precipitation is 172.98 billion m^3 annual average temperature is 17.8 , and annual hours of sunshine is less than 1,900. In the whole province, the total forest area is 6,159.6 hectares (ha) and the percentage of forest cover is 54.6%, giving a total wood storage capacity of 112.457 million m^3.

Zhejiang has a moderate climate, ample rainfall, advanced agriculture in the plains, and abundant straw and stalk resources. The percentage of forest cover ranks first among the provinces in the main land of China. In all the 86 cities and counties, the fuelwood resource is very rich in 58 mountain counties particularly in Lishui and the southern mountain areas of the province.

The development potential of biomass is very great. There exist 436 state-owned farms, animal farms, and stud farms in the province. All these farms have the qualification for building large and medium-size biomass stations. If the excrement and dung of the livestock can be processed by anaerobic fermentation, the biomass produced per year will be 24.09 million m^3, equal to 669,000 cylinders of liquefied petroleum gas (LPG) which can meet the consumption of 66,000 households. If all the excrement and dung discharged by the livestock and animals raised by farmers in the province can be utilized, 1.433 billion m^3 biomass would be produced, namely, 1.0325 million tons coal equivalence (tce), 5% of which has been exploited. In addition, the winery and food product factories in the cities and towns can turn the waste into resource by biomass engineering, and thus mitigate the problem of energy and environmental protection. It is a market with great potential.

There are abundant waterpower resources. Because of the terrain to the northeast,

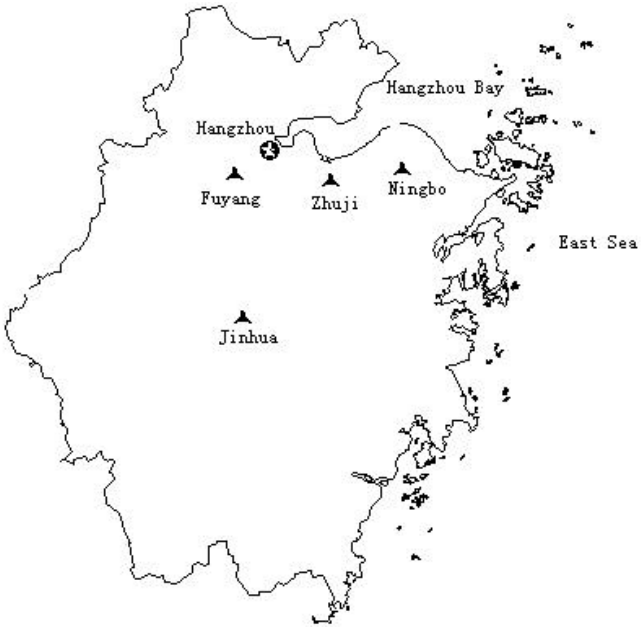


Figure 7.1 Zhejiang administrative region

there are many mountains with heights over 1,000 meters. In southeast Zhejiang, there are hills with altitudes of about 500 meters in the mid-Zhejiang, and there are plains in the northeast Zhejiang. Eight rivers, namely, Qiantang River, Wu River, Tiaoxi River, Feiyun River, Xu River, Cao'e River, Ao River, and Yong River, cross over the whole province, which shape the geographical condition of a rich water-power resource. The reserve of waterpower resource over the whole province reaches 5,874 megawatts (MW), the exploitable quantity is 3,227 MW, and about 25% of small hydropower resources have been developed.

The degree of solar energy utilization in Zhejiang Province falls into Class 4 region. Though inferior to some provinces in the Northwest China, it is still a clean, stable, and inexhaustible nature resource. There are 1,990 hours of sunshine per year in the province and the average gross amount of annual solar radiation is 4.7 GJ/m^2. In recent years, progress has been made on the spread of solar water heaters, utilization of plastic greenhouses to cultivating fruit and vegetable, and use of solar dryers.

7.1.2 Features of energy production, supply and consumption

7.1.2.1 General situation of energy construction of the province

In recent years, with the amazing economic growth, energy consumption rose greatly. The contradiction between energy supply and demand grows increasingly, the shortage of commercial energy supply in the province rises gradually and, the

Table 7.1 Basic data of Zhejiang Province and its rural area

Item	Unit	1990	1994
Gross output value of industry and farming of the province	billion RMB Yuan	177.093	649.214
Population of the province	million	42.3491	43.412
Urban household per capita net income	Yuan per year	1,931.78	5,069.57
Gross output value of farming, forestry, animal husbandry, and fishery products in China	billion RMB Yuan	33.604	70.721
Natural growth rate of the rural population	%	7.0	5.5
Rural household number	million	10.3455	10.6662
Rural household per capita net income	RMB Yuan per year	1,099.04	2,224.64
Growth rate of rural household per capita net income	%	8	27
Gross output value of industry (GOVI)	billion Yuan	143.416	578.493
In which, GOVI of TVEs	billion Yuan	45.265	176.768
Percentage of GOVI	%	31.56	30.56
Number of town and village enterprises (TVEs)	million	0.494	0.8636
Gross output value of TVEs*	billion Yuan	77.248	475.992
Number of employees	million	4.9549	7.7389
Total population	million	42.3491	43.412
In which farming population	million	35.3815	35.6519
Rural household number	million	10.3455	10.6662
Rural population	million	35.5079	35.8423
Rural labor force	million	20.3477	21.013
In which, labor in farming, forestry, animal husbandry and fishery	million	13.365	11.8743
Total agriculture mechanical power	million kW	12.1574	14.9734
Cultivated/irrigated area	1,000 ha	1,723.53/1,429.39	1,635.47/1,363.37
Gross output value of farming	billion Yuan	33.604	70.721
Gross nonagricultural output value in rural area	billion Yuan	80.258	489.463
In which, gross output value of industry	billion Yuan	66.153	442.624
1. output value of Towns enterprises	billion Yuan	31.915	154.842
2. output value of Villages enterprises	billion Yuan	20.474	95.604
3. output value of other enterprises	billion Yuan	13.764	192.178
Grain output/sown areas	million tons/1,000 ha	15.861/3,266	14.04/2,741.04
In which,Cereal output/sown areas	million tons/1,000 ha	15.004/3,000.69	13.1757/2,453.83
Cotton output/sown areas	million tons/1,000 ha	0.0642/68.67	0.0554/61.66
Hemp corps output/sown areas	million tons/1,000 ha	0.146/23.43	0.0489/7.7
Oil bearing crops output/sown areas	million tons/1,000 ha	0.4835/302.05	0.3459/235.42

(Continued)

Tubers output/sown areas	million tons/1,000 ha	0.6278/11.67	0.7014/13.26
Tea output/sown areas	million tons/1,000 ha	0.117/162.87	0.1069/143.35
*mu*lberry areas	1,000 ha	87.23	101.32
Orchard areas	1,000 ha	221.61	229.94
Fruit	million tons	1.0701	1.7586
In which, citrus fruit	million tons	0.7973	1.3927
Meat	million tons	0.9613	1.1471
In which, pork, beef, mutton	million tons	0.8563	0.9814
Cow milk	million tons	0.1127	0.0968
Sheep wool	million tons	0.0026	0.0023
Honey	million tons	0.063	0.0424
Poultry eggs	million tons	0.1899	0.3313
Mulberry silkworm cocoons	million tons	0.1180	0.1338
Hogs at year-end	million	13.3045	12.7968
Cattle and buffalo at year-end	million	0.6801	0.5072
Sheep and goats at year-end	million	1.8507	2.0598
Aquatic products	million tons	1.3898	2.5801
1. seawater aquatic products	million tons	1.1317	2.2229
2. freshwater aquatic products	million tons	0.2581	0.3572
Number of TVEs/population	million/million persons	0.494/4.9549	0.863568/7.7389
In which, number of village enterprises/ population	million/million persons	0.0853/3.5236	0.075915/2.6022
Gross output value of TVEs	billion Yuan	77.248	475.992
In which, output value of industry	billion Yuan	70.776	442.624
Rural living			
Rural household per capita net income	Yuan	1,099.04	2,224.64
Rural household per capita total expenditures	Yuan	1,337.76	2,488.47
Gross output value of farming, forestry, animal husbandry and fishery	billion Yuan	34.762	44.211
In which, gross output value of farming	billion Yuan	20.317	22.883
Gross output value of forestry	billion Yuan	1.773	3.024
Gross output value of animal husbandry	billion Yuan	7.815	8.892
Gross output value of fishery	billion Yuan	4.857	9.412

* TVEs = Total village enterprises

kerosene oil consumption in the TVEs also increases. On the other side, rural energy (including natural energy resources) is still being ignored or used with low efficiency at low levels. The basic statistics about energy consumption in the province are shown in the following tables.

Table 7.2 Situation of main commercial energy supply and demandin Zhejiang Province

Item	Unit	1990	1994
Coal production	million tons	1.3672	1.2928
Coal consumption	million tons		38.8939
Power generation	TWh*	20.858	32.44
Power consumption	TWh	23.029	39.674
Total energy consumption in which, living consumption is:	million tce	25.8086	42.4670
urban living consumption	million tce	1.698	2.4013
rural living consumption	million tce	0.897	1.597

*TWh = Terawatt-hours

Table 7.3 Growth rate of GDP, energy production, and consumption

Item	Unit	1990	1994
GDP* growth rate than last year	%	3.9	20.0
Energy production growth rate than last year	%	-10.08	3.53
Energy consumption growth rate than last year	%	4.54	11.19
Power generation growth rate than last year	%	4.15	10.50
Power consumption growth rate than last year	%	8.46	14.42

*GDP = Gross Domestic Product

Table 7.4 Average daily energy consumptionby energy type in Zhejiang Province

Item	Unit	1990	1994
Total	1,000 tce	70.7	116.3
Coal	1,000 tce	68.1	106.6
Coke coal	1,000 tce	2.3	3.3
Crude oil	1,000 tce	6.7	14.4
Fuel oil	1,000 tce	2.8	3.3
Gasoline	1,000 tce	1.6	3.1
Kerosene oil	1,000 tce	0.2	6.2
Diesel oil	1,000 tce	3.6	6.7
Electrical power	GWh*		109

* GWh = Gigawatt-hour

Table 7.5 Energy consumption in industry and TVEs in Zhejiang Province

Item	Unit	1990	1994
Total energy consumption in industry in the whole province	million tce	18.9754	27.0000
In which, energy consumption in TVEs	million tce	5.906	9.0843
Percentage	%	31.12	33.6

Table 7.6 Energy consumption in TVEs by energy type

Item	Unit	1990	1994
Raw coal	million ton	5.141	9.7626
Coke coal	million ton	0.1514	0.3445
Fuel oil	ton	11,853	38,425
Kerosene oil	ton	4,879	15,190
Gasoline oil	ton	91,146	137,569
Diesel oil	ton	103,413	201,424
Electricity	TWh	4.856	10.652

Table 7.7 Energy consumption percentage of the sectors in the industry (%)

	Food	Textile	Paper-making	Chemical	Plastic	Building material	Electric-mechanic	Other	Total
Province	6.13	11.15	3.48	18.11	1.66	21.37	5.31	32.79	100
TVEs	3.70	20.34	3.32	4.12	2.61	39.74	6.39	19.78	100

Table 7.8 Summary of rural energy consumption

Item	Unit	1990		1994	
Total rural energy consumption	million tons	14.5932		25.1373	
Rural living energy consumption (RLEC)					
Everage annual personal energy consumption	tons	0.22		0.31	
Subtotal	million tce	7.942	percentage of RLEC	11.2553	percentage of RLEC
Straw and stalk/equiverlent	million tons/tce	7.8702/3.3729	42.5%	7.08/3.27	29.1%
Fuelwood/quiverlent	million tons/tce	6.7462/3.8521	48.5%	8.74/5.00	44.5%
Raw coal/quiverlent	million tons/tce	0.5420/0.387	4.9%	1.65/1.17	10.4%
Oil/quiverlent	million tons/tce			0.1/0.150	13.3%
Gas fuel/quiverlent	million m^3/tce	111.66/0.1236	1.5%	310/0.344	3%
Electricity/quiverlent	TWh/tce	1.68/0.2064	2.6%	10.62/1.3	11.6%
Rural production energy consumption (RPEC)					
Subtotal	million tce	6.6512	percentage of RLEC	13.882	percentage of RLEC
Raw coal/quiverlent	million tons/tce	5.4708/3.9077			
Coke coal/quiverlent	million tons/tce	0.1514/0.1428	2.1%	0.23/0.22	1.6%
Oil/quiverlent	million tons/tce	0.8619/1.3447	20.2%	1.71/2.56	18.5%
Fuelwood/quiverlent	million tons/tce			1.29/0.74	0.3%
Stone coal/quiverlent	million tons/tce	2.8262/0.6056	9.1%		

Note: Taking 16, 720 kJ/kg as the caloric value of the fuelwood; taking 12,540 kJ/kg as the caloric value of the straw and stalk; taking 20,900 kJ/kg as the caloric value of raw coal.

7.1.2.2 Status of rural energy Consumption

The rural energy consumption falls into two categories. One is rural living energy consumption, and the other is rural production energy consumption. The latter consists of production energy consumption, rural transportation energy consumption, and energy used by TVEs.

As shown in Table 7.8, with the development in rural areas, particularly TVEs in recent years, the percentage of rural production energy consumption decreased from 54% to 45%. In the rural living energy consumption, biomass energy takes the prevailing position. However, with the economic development and the improvement of lifestyles in recent years, the percentage of available high quality fuel increased gradually. The ratio of straw, stalk, and fuelwood reduced from 91% in 1990 to 73% in 1994. In the rural energy consumption, the percentage of commercial energy increased from 50% in 1990 to 64% in 1994.

7.1.2.3 Status of the rural energy development

Biogas is a kind of high-quality cooking fuel. The use of biogas digesters can provide energy and alleviate the environmental pollution. During the Eighth Five-Year Plan, the number of the households with biogas digesters reached 2% of the total rural households. Recently, because of the economic development and the change of raising poultry and animals, there are increasing numbers of special animal raising households. The small household biogas digester continues the trend of medium-size biogas digester suitable for the special animal households. In addition, with the scale production, centralized management, gas supply by pipeline, providing production energy and residential cooking energy, conspicuous benefit of environmental protection and integrated utilization, the large size biogas project has a much wider prospective market. In the past years, many livestock farms, breweries, and food processing factories have built biogas stations. At the same time, with the urgent environmental protection measures, it becomes a new issue to make wastewater of urban biogas clarifier tanks meet the emission standards. There are no centralized wastewater processing systems in small towns and no wastewater pipe network in some suburbs. Beneficial environmental results can be realized by processing the wastewater of public toilets, hospitals, apartments, and office buildings with the biogas clarifier tanks. Some county and cities have promoted the spread and application of biogas clarifier tanks through issuing documents by the local governments.

In the development of natural resources, except the sustainable development of the wind energy and small hydropower, the utilization of solar energy has increased greatly, In particular, the solar water heater exceeded 10,000 m^2 by 1994. The solar water heater is safe and nonpolluting. The evacuated tubular solar water heater developed in recent years can meet the requirements of bathing in the winter, which

Table 7.9 Summary of rural energy construction data

Item		1990	1994
Household biomass digester	Number of the new users	1,772	659
	Total *(1,000)	226.99	183
	Total gas production (10^6 m^3)	35.9106	32.4181
Large and edium-size biogas project	Number of the new		2 sites 2 projects
	Total*		1,400
Improved cookstove	Number of the new	91.0469	21.88
	Total*	583.409	837.06
Wind energy	Number of the new	19 sets/114.3 kW	12 sets/88.2 kW
	Total*	80 sets/405.31 kW	88 sets/951.1 kW
Small hydro power	Number of the new	33 sets/13.8 kW	151 sets/171.27 kW
	Total*	199 sets/1,151.8 kW	549 sets/695.54 kW
Plastic greenhouse	Total	4,450.97	77,904.0
Solar water heater	Number of the new	2,994.65	15,674.0
	Total*	18,687.88	4,347.0
Energy saxing tea stove	Number of the new	9509	8283
	Total*	19,824, 54,369.1 ton tea parched per year, annual energy saving of 20,865.5 tce	60,222, 71,571.3 ton tea parched per year, annual energy saving of 56,745.5 tce
Energy saving brick	Number of the new	474	842
Kiln	Total*	1,895, 3,079.162 million bricks produced per year, annual energy saving of 8,482.3	2,322, 2406.85 million bricks produced per year, annual energy saving of 1,055.81 tce
Agencies of rural energy dissemination		206/843 persons, and 78 agencies above the county level	169/631 persons, and 80 agencies above the county level
Institution of rural energy system		4/29 persons	11/61 persons
Specialty service team		85/1,870 persons, remodel biogas digester	55/585 persons engineering implementation
Industry building		19/1,290 persons, output value of 7.0094 million Yuan	124/14.35 persons, output value of 28.979 million Yuan with benefit of 2.7689 million Yuan
Service system		99/620 persons, turnover of 15.7554 million Yuan with benefit of 0.8685 million Yuan	105/1,230 persons, turnover of 384.1928 million Yuan
Financial input	Total	4.6083 million Yuan	31,611.1887 million Yuan
		in which, 0.643 million Yuan from province & cities 3.1079 million Yuan from counties	in which, incentives of 0.387 million Yuan from State 0.869 million Yuan from province & cities 4.4182 million Yuan from counties 155.3396 million Yuan by self raise

* The actual operation number, excluding the number of the eliminated and idle.

promotes solar water heaters further. Moreover, utilizing the solar dryer, vegetables and fruit planted in the sunshine plastic greenhouse, would receive good economic benefits and social benefits. These have had great developments in recent years.

With the economic development and enhancement of farmers' incomes, the percentage of high-quality energy such as electricity, gas, and coal, has increased gradually in rural . For example, the rate of LPG for rural cooking energy rose from 6.6% in 1990 to 24% in 1994.

Energy conservation is always a key element in the rural construction. Improved stoves and tea parching stoves are the conventional energy saving projects. The dissemination rate of improved stoves increased from 56% in 1990 to 87% in 1994 (4.78 million tce saved per year). The number of the improved tea parching stoves was over 60,000 by the end of 1994. The amount of tea parched every year exceeds 70,000 tons, thus 57,000 tce could be saved. In addition, there is high-energy consumption in TVEs and serious environmental pollution. Energy conservation in TVEs is a new field to be developed immediately. Lately, it has received more attention.

7.1.2.4 Supply and demand forecast

According to the national economic development plan, increasing planning of rural population and rural energy consumption development trend during the Eighth Five-Year period, the rural living energy consumption, production energy consumption and supply and demand status in 2000 and 2010 have been predicted. The results are shown in Table 7.10.

Table 7.10 Rural energy consumption forecast in 2000 and 2010

Item	1990	1994	2000	2010
Rural population (million)	35.5079	35.8423	38.644	39.560
Rural living energy				
Fuelwood PQ/tce (milion)	6.7462/3.8519	8.7452/5.0063	10.145/5.808	11.344/6.464
Straw &stalk PQ/tce(million)	7.8702/3.3729	7.0875/3.2723	6.540/3.020	5.757/2.658
Coal PQ/tce (million)	0.542/0.3871	1.6453/1.1746	2.418/1.726	3.080/2.198
Gas fuel m^3/tce (million)	111.6680/0.1236		509.311/0.5638	867.194/0.960
Electricity Twh/million tce	1.68/0.2066	10.616/1.3084	19.55/2.4097	32.06/3.962
Subtotal/million tce	/7.79421	/11.1053	/13.528	/16.262
Average personal energy consumption (1,000 tce/year per person)	2.2	3.1	3.5	3.9
Production energy				
Coal PQ/tce (million)	5.4708/3.9077	12.5735/9.051	15.374/10.978	26.308/18.957
Stone coal PQ/tce (million)	2.5262/0.6056	4.1004/0.9830	5.5013/1.178	7.978/1.700
Oil PQ/tce (million)		1.712/2.5637	2.267/3.394	
Electricity TWh/million tce	5.253/5.504	12.021/13.125	16.65/18.18	35.35/38.60
Subtotal/million tce				31.640
Total (million tce)		24.9114	30.896	47.902

* PQ = physical quantity

Table 7.11 Rural energy supply-demand forecast in 2000 and 2010

Item		2000	2010
Supply available	Fuelwood PQ/tce (million)	21.4823/12.2691	59.3382/33.8896
	Gas fuel m^3/tce (million)	100.6780/0.1679	400.9378/0.6686
	Coal PQ/tce (million)	0.1021/0.0729	0.0926/0.0661
	Stone coal PQ/tce (million)	5.5013/1.1789	7.9782/1.7096
	Electricity TWh/million tce	1.996/0.2455	4.351/0.5352
	Subtotal (million tce)	/18.9322	/42.4033
Demand available	Fuelwood PQ/tce (million)	10.145/5.808	11.344/6.494
	Straw and stalk PQ/tce (million)	6.540/3.020	5.757/2.658
	Gas fuel m^3/tce (million)	509.311/0.5638	867.194/0.960
	Coal PQ/tce (million)	17.792/12.704	29.388/21.155
	Stone coal PQ/tce (million)	5.5013/1.178	7.978/1.709
	Electricity TWh/million tce	36.20/4.228	67.41/7.812
	Subtotal (million tce)	/30.896	/47.902
Shortage	Fuelwood PQ/tce (million)	11.3373/6.4611	47.994/27.396
	Straw and stalk PQ/tce (million)	5.110/1.978	7.143/2.8762
	Coal PQ/tce (million)	-17.690/-12.630	-29.295/21.089
	Oil PQ/tce (million)	-2.267/-3.394	-4.750/-7.114
	Electricity TWh/million tce	-34.204/-3.983	-63.06/-7.276
	Subtotal (million tce)	/-11.9639	/-5.659
	In which, commercial energy	/-20.403	/-35.931
	Biomass energy *	/8.439	/30.272

*Excluding excrement waste

Energy price (articles for daily use): besides parts available from straw and stalk, fuelwood (only labor force needed), more and more farmers purchase commercial energy.

The costs for various living energy sources are as follows:

Liquefied petroleum gas: two to six cylinders per year, 50 Yuan per cylinder
Coal: 400 Yuan/ton
Fuelwood: 200 to300 Yuan/ton
Biogas: 0.6 to1.0 Yuan/m^3
Electricity: 0.3 to 0.5 Yuan/kWh

7.2 The Distribution of Biomass Energy Resource

There are three types rural energy that can be developed in Zhejiang Province. They are biomass energy, conventional energy, and other natural energy. The biomass

energy includes straw and stalk, excrement, and biomass waste. Conventional energy includes small and mini hydropower, coal from small coal pits, stone coal, and natural gas. Natural resources include solar energy, wind energy, tidal energy, geothermal energy, and so on. The quantities of every kind are listed in the following tables.

Table 7.12 Exploitable quantity of fuelwood

Item	1990	1994
Exploitable quantity (million tons)	6.8182	8.927
Million tce	3.9032	5.1104

Table 7.13 Summary of straw and stalk resource of the whole Province

Type	Output (million tons)		Ratio of grain to grass	Straw and stalk in theory (million tons)		Low caloric value (kcal)*	Fraction of collection	Exploitable quantity (million tce)	
	1990	1994		1990	1994			1990	1994
Wheat	1.6410	0.5438	1:1	1.641	0.5438	3,500	0.5	0.4103	0.1360
Rice	13.214	13.1757	1:1	13.214	13.1757	3,000	0.5	2.8316	2.8234
Corn	0.128	0.126	1:2	0.2560	0.252	3,700	1	0.1353	0.1332
Soybeans	0.124	0.2933	1:1.5	0.186	0.440	3,800	1	0.1010	0.2389
Tubers	0.557	0.5710	1:1	0.557	0.571	3,400	1	0.2705	0.2773
Oil-bearing	0.4835	0.3459	1:2	0.967	0.6918	3,700	1	0.5111	0.3656
Sugarcane	0.6278	0.7014	1:0.1	0.0628	0.0701	3,300	1	0.0296	0.0331
Cotton	0.0642	0.0554	1:3	0.1926	0.1662		1	0.1046	0.0903
Hemp	0.1452	0.0489		0.2468	0.0831	3,700	1	0.1305	0.0430
Total								4.5245	

*kcal = kilo calorie

Table 7.14 Summary of biogas resource of the whole Province

Item	Year	Pig	Sheep & Goats	Cattle	Poultry
Number of raising (million head)	1990	13.3045	1.8507	0.6801	70.1295
	1994	12.7968		0.5072	92.5938
Quantity of excrement every day per animal (kg)		2	0.25	10	0.05
Ratio of dry dung		0.2	0.4	0.18	0.8
Fraction of collection		1	0.6	0.6	0.6
Exploitable fraction		0.8	0.8	0.8	0.8

Annex 1

Research on the Availability of Biomass Resource in Xiaoshan, Zhejiang Province

A1.1 Gross economic conditions of Xiaoshan and analysis on the trend of energy consumption

A1.1.1 Gross economic conditions of Xiaoshan

In 1995 the city's GDP value was 12,344.3 million Yuan, 23.1% higher than that of 1994. And its gross industrial and agricultural output value reached 31,422.4 million Yuan, 18.4% higher than 1994, in which, the gross industrial output value was 30,354.4 million Yuan, 18.9% higher than the last year. Per capita annual income of rural household was 3,893 Yuan, 29% higher than 1994, while per capita annual actual income of urban household was 6,189 Yuan, 16.3% higher than 1994. Total budgetary revenue was 824.89 million Yuan, 14% higher than 1994.

A1.1.2 Analysis on the trend of energy consumption

The energy resources of Xiaoshan can be divided into three parts (the data below have been converted into standard coal equivalent):

- Biomass energy resource (mainly includes husk and stem of crops and excrete of livestock): The output value was 1.049 million tons, and the physical volume was 570,300 tons, in which, 231,000 tons for energy consumption. The utilization rate was 40.5%.
- Commercial energy: Totally 819,000 tons, in which, 497,000 tons from electricity, 182,000 tons from oil, and 132,000 tons from coal. The commercial energy consumption for rural living and production was 417,000 tons, 50.9% of the total.
- Natural energy resources: The amount which have been utilized is very small. Just 56 tons from small hydro power, 38 tons from solar energy collectors.

Calculated with the actually consumed fuels and electricity, energy consumption for rural production and living was 672,000 tons, 48.7% of the total energy consumption of the city.

From the analysis mentioned above and the future development of rural area, it is clear that rural energy has taken an important position in the city's energy strategy. The reasons are in the following:

- The actually consumed fuels and electricity of rural energy have closely reached 50% of the total.
- With the increase of rural living standard and the development of production, the energy consumption is rising day by day, and its percentage in the city's total consumed energy is becoming larger and larger.
- The current utilization rate of rural energy is the lowest. Also there are a lot of poor fields. Attention should be highly paid.

A1.2 Analysis on biomass energy resources

From Table A1.1 and Table A1.2, the total amount of husk and stem and livestock excrete is 350,000 tons, 42.7% of the city's total commercial energy, or 819,000 tons. If it can be fully developed and utilized, more than half of rural energy consumption can be achieved. Thus the development of biomass energy resources is an effective solution to rural energy consumption problem.

A1.3 Research and analysis on the availability of biomass energy resources

A1.3.1 Resource density

Due to the differences in such factors as natural conditions, geographical distribution of crops and the development of livestock breeding industry, the different towns and villages occupy different amount of biomass resources. If average annual 330 kg per capita and average annual 130 m^3 per capita are set as standard indices respectively for firewood resource and biogas resource of the whole city, the figures below these two figures mean lack, while the figures over the two indices mean general, then the biomass energy resources in the towns and villages of the city can be divided into three regional categories, which is shown in Table A1.3. Due to the less people and vast land, farms belong to the third category.

A1.3.2 Collection cost of biomass energy resources

From Table A1.4 and Table A1.5, for husk and stem and livestock excrete, the collection cost is low. If it can be converted into heat power or electric power, the related social, environmental and energy benefits will be great.

A1.4 Suggestion on utilization of biomass energy resources

A1.4.1 Introduction and dissemination of gasification and generation technologies of husk and stem

1) In the east area where the resource of firewood and grass is relatively abundant, the gasification technology can be introduced with each village taken as a unit so as to solve the fuel problem. On such basis, for the surplus resource, taking each town as a unit, the suitable gasification and generation device using husk and stem should be installed so as to meet some electricity demand.

2) In the regions where the biomass resource is general, the gasification technology of husk and stem can be introduced and disseminated so as to increase the heat efficiency and meet the farmers' energy demand for living.

A1.4.2 Actively develop biomass energy projects taking biogas as the key

The city has relatively developed livestock breeding industry. In the whole city there are two hoggeries with more than 10,000 pigs each, seven with 5,000 to 10,000 pigs each, 319 with less than 5,000 pigs each. The total biomass resource reaches 26,724 tons. So biogas project can be constructed according to the scale of the hoggery. As for the hoggery with more than 5,000 pigs, the produced biogas is mainly provided to generate electricity for its own production and living consumption, except a small amount used as civil fuels. For the hoggery with less than 5,000 pigs, the biogas is the main product and supplied as fuel for its own consumption. For the other livestock breeding farms, medium and small size biogas projects should be developed according to their own conditions.

Case I: General agriculture conditions of Qianjiang Farm

The farm is located in the northwest of Xiaoshan, separated with Hangzhou by the river. In 1995 its total area of cultivated land was 6,817 *mu*, in which, 4,915 *mu* for spring grains (456 *mu* for rape), 158 *mu* for early rice, 6,343 *mu* for late rice, 196 *mu* for cotton.

The farm has a 10,000-pig hoggery. In the whole year of 1995 the reared pigs were 13,656, in which, 5,787 were sent to market, the other 7,869 were on hand by the end of the year.

Case II: Conditions of enclosing tideland for cultivation

The tideland area enclosed for cultivation in Xiaoshan is 31 kilometers long in north-south direction, 26 kilometers long in east-west direction, with the total area of 420,000 *mu*, in which, cultivation area is 240,000 *mu*. In 1995 109,000 *mu* was developed for cotton planting, with the per *mu* output of 68 kg. And its output of husk and stem was 22,236 tons, or 12,070.95 tce. 23,200 *mu* was developed for hemp planting, with the per *mu* output of 463 kg. And its output of husk and stem was 18,260.72 tons, or 9,652.09 tce. 51,500 *mu* was developed for rapeseed planting, with the per *mu* output of 107 kg. And its output of husk and stem was 11,021 tons, or 5,825.39 tons of standard coal equivalent.

Due to the less people and vast land in this area, as well as the low population density and relatively advanced village and town enterprises, it is suggested that electricity generation be the main application and civil use be supplement after the introduction of gasification technology of husk and stem.

Table A1.1 Resource conditions of husk and stem of crops

Crop variety	Early rice	Late rice	Barley	Wheat	Soy-bean	Cotton	Hemp
Annual planting area (1,000 *mu*)	279.6	555.0	65.0	193.3	204.2	109.5	23.2
Per *mu* output (kg)	375	444	203	317	138	68	463
Annual output of husk and stem (tons)	83,880	197,136	26,390	122,679	56,359	29,784	18,261
Standard coal equivalent (tons)	35,949	84,487	13,195	61,340	30,595	15,168	10,043
Crop variety	Rape	Horse-bean	Peanut	Other grain	Vege-table	Others	Total
Annual planting area (1,000 *mu*)	128.5	26.9	12.8	21.3	227.2	79.7	1926.4
Per mu output (kg)	442	138	138	271	2,199		
Annual output of husk and stem (tons)	113,594	56,369	3,532	10,390			
Standard coal equivalent (tons)	60,043	5,140	1,917	4,452			323,320

Table A1.2 Resource conditions of livestock excrete

Livestock variety	Pig	Cattle	Sheep	Poultry	Total
Annual number on hand (1,000)	246.4	1.9	16.7	4,630	
Annual output of excrete (tons)	52,483	2,787	1,352	4,167	
Standard coal equivalent (tons)	22,493	1,314	715	2,202	26,724

Table A1.3 Categories of biomass energy density of Xiaoshan

	Resource of firewood and grass	Resource of biogas	Village and town, farm
I	lack	lack	Louta, Dai Village, Yunshi, Xuxian, Jinhua, Suoqian, Kanshan
II	lack	general	Heshang, Puyang, Huantan, Linpu, chengxiang, Yiqiao
III	Variety	general	Yaqian, Xinjie, Ningwei, Dangwan, Toupeng, Xinwan, Yisheng, Jingjiang, Nanyang, Hezhuang, Xinwei, Qianjin, Guali, Dangshan, Yinong, each farms

Table A1.4 Collection cost of main husk and stem (Yuan per ton)

Crop name	Cotton	Hemp	Wheat	Rice	Rape
Collection cost	200	200	140	150	140

Table A1.5 Collection cost of main livestock excrete (Yuan per ton)

Livestock name	pig	cattle	Chicken
Collection cost	40	30	60

Annex 2

Investigation on the Rural Energy Resource in Fuyang City, Zhejiang Province

Fuyang City locates in the Southwest hill areas of HangJiaHu Plain, 30 km far way from Hangzhou City. It lies in 120° of East Latitude and 30° of North Altitude, adjacent to Xiaoshang in east, Zhuji in south, Tonglu, Lin'an in west, and Yuhang, Hangzhou in north, the total area of Fuyang City is 1,829.8 square km.

By the end of 1995, there are 607.9 thousand population in Fuyang City, in which, the agriculture population is 526.0 thousand, sharing 86.5% in the total population. Compared with that in 1985, it has descended by 3.86%. The gross agricultural and industrial products reached about 20.22 billion Yuan, in which, the agricultural products is 1,375.56 million Yuan, 6.8% of the total products. The net per capita rural household income hits 3,353 Yuan, and the average salary of the workers is 5,848 Yuan, both are increased by 350% and 270%, compared with that in 1990.

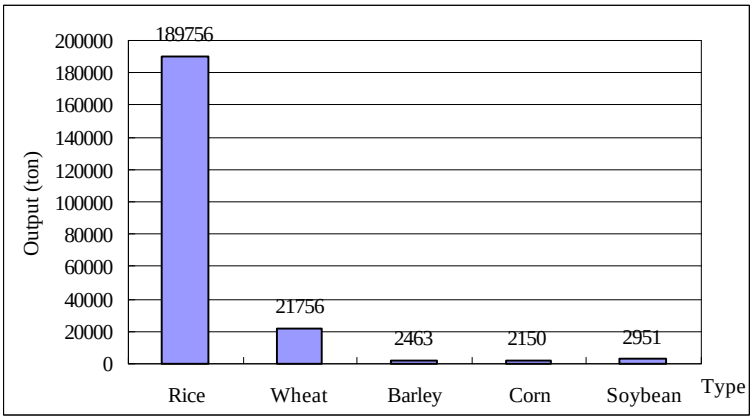
In 1995, the total electricity consumption is 621.88 million kWh, equal to 237.5 thousand tce. The electricity is consumed in the following sectors.

1) 24.83 million kWh in the agriculture, forestry, husbandry, fishery, and water conservation, 4% of the total.
2) 478.73 million kWh in industrial sector, 77% of the total.
3) 95.29 million kWh in residential sector, 15.3% of the total.
4) 3.7% in other sectors.

A. In the residential energy consumption, the average household electricity consumption in the urban residential households is 796.19 kWh, the energy for cooking is 281.35 Yuan per household; the average electricity consumption in rural residential household is 455.74 kWh; the energy for cooking is 115.68 Yuan per household. In recent years, there is great change in the residential energy consumption. The pipeline gas and LPG grow rapidly. Pipeline gas has been used in the Fuyang urban district. And a large part of the rural households has used LPG too.

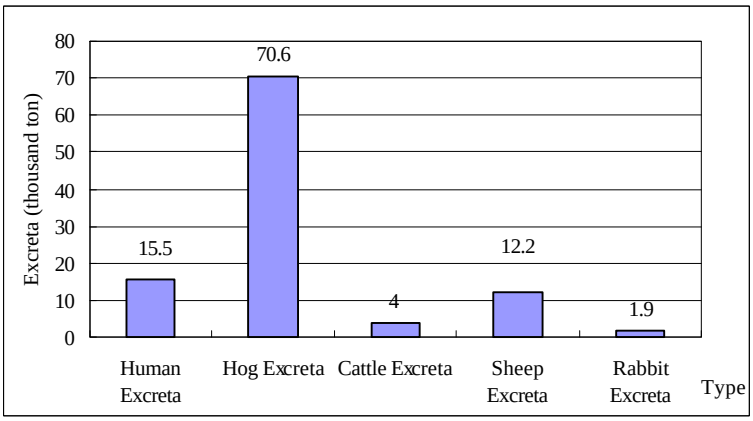
B. In the industrial energy consumption, most of the electricity, coal, coke, gasoline, diesel, kerosene are used in the enterprises. Among he fuel consumption in the Fuyang enterprises, electricity shares 30.1%, coal shares 67.8%, coke share 2.1%; and in general, the energy consumption still rely on the coal. At present, the rural energy resources also cover fuelwood, straw and stalk, and excreta of human and animals.

The total amount of straw and stalk is 219.076 thousand tons, equal to 98.5 thousand tce, the following chart illustrates the crops outputs in 1995.



The fuelwood amount is about 338.9 thousand ton, equal to 152.5 thousand ton, and whose total value is 67.78 million Yuan, which covers 10 Yuan/ton of transportation cost and 190 Yuan/ton of purchase price.

The total excreta of human and animals for agriculture is 104.2 thousand ton, which can produce 8,122 thousand m^3 biogas, equal to 6,500 tce. And the following chart is the excreta outputs in 1995.



According to the above description, there exists certain characteristics in the rural biomass energy. The fulewood still plays an important role in the rural energy, which shares about 59.2% in the total. Therefore, how to use the fuelwood becomes very important. And the straw and stalk shares 38.2%, which will improve the soil if returned to the field. The excreta resource shares little, however, the utilization rate is very high, part of which can be turned into biogas, and the other part can produce fertilizer.

Viewed from the short term, the rural energy structure is experiencing great change, and the situation of relying on biomass energy has been broken, and the ratio of electricity, oil, coal and LPG increased gradually. And the energy consumption in town and village enterprises will control the rural energy consumption.

Viewed from the long term, the situation of the energy production in China determines that it is impossible to invest more energy in the rural economic development, which will cause the scarce of energy supply in rural area, and the energy price will increase little by little. So, it is very necessary and significant to exploit biomass energy.

Attachment: The grain crops production in 1995 in Fuyang City are shown in the following .

1. Grain

Type	Plantation area (1,000 ha)	Total production (ton)	Straw output (ton)	tce
Rice	32.60	189,756	94,878	40,662
Wheat	8.43	21,756	10,878	5,439
Barley	0.88	2,463	1,231.5	615.75
Corn	0.62	2,150	4,300	2,272.86
Others	0.17	1,005	502.5	212.357
Total	42.70	232,103	111,790	49,201.967

2. Soybean

Type	Plantation area (1,000 ha)	Total production (ton)	Straw output (ton)	tce
Soybean	0.94	2,035	3,052.5	1,657.07
Broad bean	0.32	537	805.5	437.27
Others	0.20	379	568.5	308.61
Total	1.46	2,951	4,426.5	2,402.95

3. Rapeseed

Type	Plantation area (1,000 ha)	Total production (ton)	Straw output (ton)	tce
Rapeseed	5.25	7960	15920	8414.86

In sum, the total grain crop plantation area is 46.45 thousand ha, and the total production is 232,103 ton, and the straw output reaches 132,136.5 ton, equal to 60,019.777 tce.

4. Husbandry

Type	Number of sale (1,000)	Excreta (ton)	Biogas available from the Excreta (1,000 m^3)	tce
Hog	483.6	706,056	33,890.69	245,435
Cattle	5.497	40,128.1	693.414	495.446
Sheep	41.7	7,610.25	350.68	247.853
Rabbit	6.4	233.6	32.293	23.07
Fowl	2,561.2	93,483.8	12,923.2	923.251
Total		847,511.75	47,890.277	247,124.62

CHAPTER 8 Research on the Availability of Biomass Resource in Shandong Province

8.1 Introduction

8.1.1 Geography and climate

Shandong Province (Lu, in short) lies along the eastern coast of China. It is located at the lower reaches of the Yellow River, between 115 and 123 degrees east longitude, 34.5 ad 38.5 degrees of north latitude. The east Shandong Peninsula extends to the Bohai and Yellow Seas, opposite to Liaodong Peninsula. The central and south Lu are located in the Tai and Yimeng Mountain area, near the mounds. West and north Lu are a part of north China. The total area of the province is 157.6 thousand square kilometers, of which, 55% is plains, 20% is mountains, 15% is hills, 9% is lowlying land, and 1% is river and lake.

Shandong falls into the subhumid and warm temperate and monsoon climate zone. Four seasons are clearly demarcated. In spring, it is dry and windy; in the summer, muggy and rainy; in the winter, clear and dry. The average annual temperature is 11-14 , and the average frost-free period lasts for about 180-200 days. Annual precipitation varies from 550 to 950 mm from June to September. Annual hours of sunshine are 2,300-2,900, and the rate of sunlight is 52-65%. The average gross amount of annual solar radiation is about 5.0-5.9 GJ/m^2 (120-140 kcal/cm^2).

8.1.2 Socio-economic situation

The centuries-old culture and history of Shandong Province, are marked by easy access to the sea and rich mineral resources. Shandong is also one of the most important provinces for industrial and agricultural production, and always ranks among the top provinces in China for economic and produce production. Shandong teems with wheat, corn, peanut, cotton, and roasted tobacco. It is also well known as a temperate fruit zone. Shandong is also responsible for one half of all kelp and prawns produced in China. In the industrial sector, Shandong Province produces coal, oil, metals, machinery, textiles, chemicals, building materials, automobiles, and electrical power. In addition, there are many kinds of well-developed town and village enterprises (TVEs).

By 1995, the total area of cultivated land in Shandong's was 6.718 million hectares. Forest covers 18.6% of the land for a total of 2.860 million hectares. The

population of the province is 86.71 million, of which 71.24 million live in rural areas. There are 2,383 xiangs and towns, 89,000 neighborhood committees, and 19.76 million households in Shandong. The number of villages with tap water is 33 thousand, the number of villages open to traffic is up to 75,000, and the number of villages with telephone is 52,000.

In 1995, the GDP in Shandong reached 500.2 billion RMB Yuan. According to comparable pricing, GDP has increased 15.7% over 1990 and realized the second output-double ahead of 7 years. The additional value of the Primary Industry is 101 billion RMB Yuan; the secondary Industry, 238.4 billion RMB Yuan; and the Tertiary Industry, 160.8 billion RMB Yuan. The ratio for all is 20:48:32.

In 1995, the gross output value of TVEs in the whole province was 749.8 billion RMB Yuan, of which 548.9 billion RMB Yuan was industry output value and 169.1 billion RMB Yuan was industry additional value. The number of TVEs was 1.752 million, and there were 14.39 million employees, which makes up about 40% of the total number of rural laborers in the province. In the same year, the per capita income of urban residents in Shandong was 3,953 RMB Yuan, and the real per capita income of rural residents was 1,715 RMB Yuan. The problem of dressing warmly and ear one's fill has been solved on the whole, with some regions having reached a relatively comfortable living standard.

Shandong is one of the important provinces for energy production and consumption. The output value of its energy industry holds 16% of its total industry output value, including coal, petroleum oil, and electricity. In 1995, the output of crude coal was 85.13 million tons, crude oil was 30 million tons, and total electricity generated was 73.7 Terawatt-hours (TWh). Coal consumption accounts for more than 76% of its primary energy consumption. Electricity generated from coal-fired plants shares about 88% of overall electricity generation in the province.

8.1.3 The state-of-the-art of rural energy

In 1995, there were 328,000 household biogas digesters in Shandong, as well as more than 50 large and medium biogas projects and 966,000 square meters of solar water heaters. Processed shaped coal in rural areas was 5.63 million tons. The number of rural households using liquid gas, natural gas, coal gas and electric cooking were 3,139,000, 48,000, 392,000, 474,000 households, respectively. The wind energy resource is relatively rich in Shandong Province; however, the wind power industry has developed slowly. At present, there are 1,737 medium and small-size wind generators with a total installed capacity of 453.3kW, which provides electricity of 57 Megawatt-hours (MWh) per year.
The situation of rural energy consumption in 1995 in Shandong Province refers to Table 8.1 and Table 8.2.

Table 8.1 The analysis for the situation of rural energy consumption in 1995 in Shandong Province

Index	Total amount of consumption	Living consumption
Total rural energy consumption in whole Province (million TCE)*	48.388	23.802
In Commercial energy	30.760	6.438
Non-commercial energy	17.628	17.364
Ratio of commercial energy (%)	63.6	27.0
Total rural electricity consumption in whole Province (TWh)	16.72	5.12
Rural energy consumption per capita (TCE per capita per year)	0.68	0.33
Rural electricity consumption per capita (kWh per capita per year)	233.5	71.5

Source: *Shandong Rural Energy Annual Statistical Report, 1996*

Table 8.2 The situation of rural energy consumption in 1995 in Shandong Province according to energy type and use (million tons and TWh)

Type	Production	Living	Total	Type	Production	Living	Total
Crude coal	20.55	6.20	26.75	Straw and stalk		29.56	29.56
Electricity	11.6	5.1	16.7	Fuelwood	0.64	4.35	4.99
Oils	2.52	0.041	2.561	Charred coal	1.37		1.37

Source*: Shandong Rural Energy Annual Statistical Report, 1996*

8.1.4 Rural energy trend of development

The plan of Shandong's energy industry in the Ninth Five-Year Plan is to implement power-oriented and coal-based planning and conservation measures, along with overall planning to ensure that the energy demands of economic development are met. By the year 2000, raw coal production will reach 90 million tons; crude oil production will remain at 30 million tons without fluctuation; and the electricity generated will be 110 TWh with an annual growth rate of 8.3%.

With the continuous development of the rural economy and improvement of rural living standards in Shandong Province, rural energy use is moving toward commercialization and high grade. Burning straw and stalk directly is being discarded by more and more people. In areas with a more developed economy, more farm households burn coal and liquid gas, while a few of households cook with electricity. As the farmers' standard of living improves, in some areas with abundant digester stock such as that found in mountainous and hilly areas, small-size house-hold

biogas digestors have received more and more attention by farmers. There is also an upsurge in the installation of solar water heaters in rural areas and towns with tap water. At present, most solar water heaters being installed are evacuated-tube solar water heaters.

An analysis of rural energy use and high-quality energy use can be found in Tables 8.3 and 8.4.

Table 8.3 Analysis of the development of rural residential energy consumption in Shandong Province

Total Rural Energy Consumption		1991	1993	1995	2000 (forecast)
Commercial energy	Raw coal (million tons)	4.261	6.754	6.20	6.00
	Electricity (TWh)	0.73	3.755	5.12	10.0
	Oils (million tons)	0.1634	0.0874	0.041	0.10
	Subtotal (million TCE)	3.499	6.025	6.443	9.72
Non-commercial energy	Fuelwood (million ton)	2.85	3.59	4.35	6.00
	Straw & stalk (million ton)	26.30	27.78	29.65	25.00
	Biogas (million m^3)	74	80	87	200
	Water heated by solar energy(million TCE)	0.054	0.116	0.192	0.60
	Subtotal	14.831	16.109	17.559	16.16
Total (million TCE)		18.330	22.134	24.002	26.88

Source: *Shandong Rural Energy Annual Statistical Report, 1996*

Table 8.4 Status of the development of high-quality rural residential energy consumption in Shandong Province (million)

Number of Households	1991	1993	1995	2000 (forecast)
Electrical cooking	0.086	0.317	0.474	1.00
Liquid gas	1.20	2.53	3.14	5.00
Natural gas	0.006	0.032	0.048	0.05
Coal gas	0.08	0.271	0.392	0.55
Biogas	0.331	0.350	0.330	0.050
Total	1.703	3.500	4.384	7.10

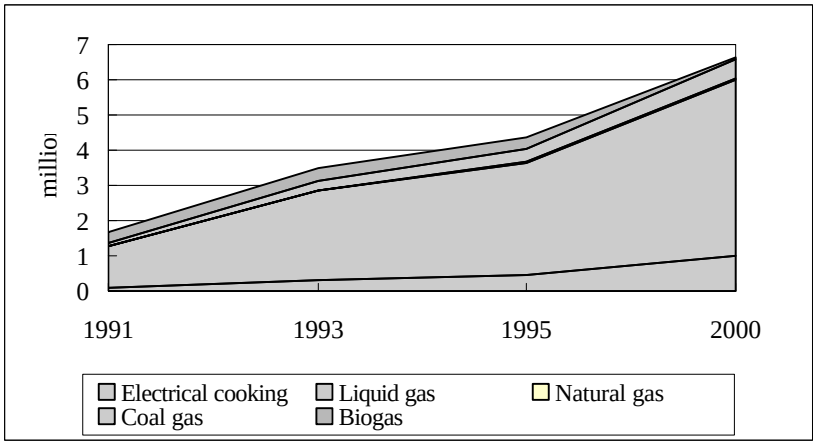


Figure 8.1 Number of households using high-quality energy

8.2 Biomass Energy

8.2.1 The development of agriculture

At the beginning of 1995, there was a real cultivated land area of 6.72 million ha (101 million *mu*) in Shandong, dry fields of 6.58 million ha, valid irrigated area of 4.64 million ha, and area ploughed by tractor of 5.51 million ha. By the end of 1995, there was orchard area of 0.935 million ha in the province.

In 1995, the total sown area was 10.837 million ha and the output of the grain, cotton, and peanuts was 42.45 million tons, 3.09 million tons and 0.471 million tons, respectively. And the output of fruits, vegetables, and aquatic products was 7.18 million tons, 41.72 million tons, and 3.809 million tons, respectively.

In 1995, there were 14.63 million large domestic animals on hand in total, of which 12.39 million were cattle on hand, and 0.382 million were cattle for sale; 24.85 million pigs on hand, and 33.28 million for sale; 45.20 million sheep on hand, and 43.88 for sale; 59.72 million rabbits on hand, and 77.99 million for sale; 660 million poultry on hand, and 1.2 billion for sale. The total amounts of meat, eggs, and milk were 5.87 million tons, 3.19 million tons, and 0.67 million tons, respectively.

There were 800,000 feedlots of different scale in Shandong. The amount of livestock in them was 40% of the total in the whole province. The number of all different livestock farms was more than 8,000. The feeding scale is moving from courtyard to centralization of scale and intention.

By the end of 1995, there were 2.379 million ha of woods and the area of farm

covered with woods reached 5.133 million ha. The intercropping area of farm crop and wood was 800,000 ha, while the stock amount of timber was 73 million m^3. Woos covered accounted for 20.2%.

In accordance with the Ninth Five-Year Plan, by the year 2000, the agricultural acreage should be at least 6.67 million ha (100 million *mu*) in Shandong, sown areas of grain and cotton no less than 7.87 million ha and 0.667 million ha, respectively. For the most part, farm mechanization will be implemented. The output of grain, cotton, peanuts, meats, and aquatic products will be 45 million tons, 0.7 million ton, 3.50 million tons, 7.00 million tons, and 5.50 million tons, respectively.

8.2.2 Total amount of straw and stalk

The area under crops, total production and theoretical storage capacity of straw and stalk in Shandong in 1995 are shown in Table 8.5.

Table 8.5 Theoretical stock of the straw and stalk of major crops in Shandong Province (1995)

Name of Crop	Sown area (million ha)	Output (million ton)	Ratio between grass and rice	Switching coefficient	Amount of straw and stalk (million tons)		
					Physical quantity	Standard coal	Percentage (%)
Total					65.47	32.51	100
Wheat	4.011	20.62	1	0.5	20.62	10.31	31.7
Corn	2.695	15.43	2	0.5	30.86	15.43	47.5
Rice		0.911	1	0.429	0.91	0.39	1.2
Bean	0.535	1.271	1.5	0.529	1.91	1.01	3.1
Potato	0.597	3.576	1	0.429	3.58	1.53	4.7
Peanut	0.850	3.090	2	0.5	6.18	3.09	9.5
Cotton	0.666	0.471	3	0.529	1.413	0.747	2.3

Source: *Shandong Statistical Yearbook, 1996*

8.2.3 Livestock waste

The number of large domestic animals, pig, sheep, rabbit, and poultry on hand and the theoretical available livestock waste in 1995 in Shandong Province are shown in Table 8.6.

8.2.4 Analysis of fuelwood reserves

The woodland area and fuelwood reserves in 1995 are shown in Table 8.7.

Table 8.6 Theoretical available waste of main livestock in Shandong Province (1995)

Classification	Amount of livestock on hand (million)	Amount of livestock waste (kg/day)	Collection coefficient	Switching coefficient	Available Amount of Livestock Waste (million tons)		
					Physical quantity	Standard coal	Percentage (%)
Total					112.88	57.30	100
Cattle*	12.39	20	0.6	0.471	54.28	25.57	45
Horse, Ass, Mule	2.24	15	0.6	0.529	7.36	3.89	7
Pig	24.85	4	1	0.429	36.29	15.57	27
Sheep	45.20	0.5	0.6	0.529	4.95	2.62	4
Rabbit	59.72	0.1	1	0.529	2.18	1.15	2
Chick	603.92	0.1	0.6	0.643	13.22	8.50	15

* including 73.3 thousand milk cattle.

Source: *Shandong Statistical Yearbook, 1996*

Table 8.7 Woodland area and fuelwood reserves in 1995 in Shandong

Tree Type	Area (million ha)	Firewood output per unit area (kg/ha)	Available area coefficient of fuelwood	Developable amount (million tons)		
				Physical quantity	Standard coal	Percentage (%)
Total				5.76	3.29	100
Firewood forest	0.094	7,500	1.0	0.705	0.403	12.25
Timber forest	0.652	1,500	0.7	0.684	0.391	11.88
Protection forest	0.981	750	0.5	0.368	0.210	6.38
Shrub forest	0.349	750	0.7	0.171	0.098	2.98
Open forest	0.027	1,200	0.7	0.022	0.012	0.36
Economic forest	0.935	1,200	1.0	1.122	0.641	19.48
“Four sides” forest (million)	1,343.81	2 kg per strain	1.0	2.688	1.536	46.69

8.3 Analysis of the Availability of Straw and Stalk for Energy Use

8.3.1 The usage and distribution of straw and stalk

The straw and stalk of crops can be burned directly as a rural energy source. In the 1960s and 1970s, due to the low agricultural production level, the output of grain was low and that for crop straw and stalk was ever lower; plus there was the low fuel efficiency of the old stoves. All of this resulted in a shortage of fuelwood for farmers to burn; as a result, they cut anything that could be burned, and the ecology was damaged. Unlike in the past, there is now a considerable surplus of straw and stalk. And a lot of the straw and stalk is burned in the fields in vain, which leads to smoke rising from all directions in the harvest season. How to make use of the straw and

stalk of crops has become a problem at every level of the agricultural sector.

In addition to the direct burning of straw and stalk for fuel, there are the following ways of converting and using straw and stalk: returning them to the fields directly, returning them to the fields after consumption, producing edible fungi, and anaerobic digestion for integrated use. And as industrial stock, straw and stalk can be converted into high-quality energy by gasification and solidification.

The use of straw and stalk will vary in light of the type of differences of the straw and stalk. There many uses of wheat straw and stalk, such as fuel, building material, paper making from raw material, ammoniated fodder, and returning them directly to the fields. With the improvement of the mechanized harvesting ratio, a large part of the wheat straw and stalk is returned to the field. However, the results of returning the straw and stalk to the fields is good, because the rainy season after the wheat harvest will quickly decay the straw and stalk.

The uses of corn are: household fuel, fodder, silage fodder, industrial raw material, etc. In order not to affect the current wheat growth in winter, the straw and stalk of corn must be crumbled and the land must be tilled deeply. The mince of straw and stalk and deep tillage require the operation of large farm equipment, which make the cost of returning them to the fields high. The most promising use of corn straw and stalk is as silage fodder, which not only extends and adjusts the supply time of straw and stalk fodder, but also maintains and increases the nutritional ingredient and saves a lot of fine fodder.

The straw and stalk of peanut and sweet potato are mainly put to directly use as fodder direct. In general, sweet potato and peanut are centralized in the hilly and mountainous areas, and the distribution density is not high. Therefore, all of them can be used. Besides use as a household fuel, the straw and stalk of cotton can be used as industrial-processing raw material, that of the haulm can be use as the heat insulating material of the great shed.

The output, use, and distribution of the straw and stalk of crops in 1995 and 2000 are shown in Table 8.8.

8.3.2 Status of straw and stalk

According to the annual rural energy statistics for 1995, the amount of the straw and stalk of crops used directly as household fuel in Shandong was 29.56 million tons. In 1995, the amount of silage ammoniated fodder in the whole province was 19.17 million tons, including ammoniated fodder of 6.06 million tons.

Table 8.8 Straw and stalk output, use and distribution in 1995 and 2000

Type of crop	Grain output (million tons)		Straw and stalk output (million tons)		Percentage shared by straw and stalk	Main use	Growing district
	1995	2000	1995	2000			
Total			65.47	70.91	100		
Grain	42.05	45.00					
Wheat	20.62	21.50	20.62	21.50	31	fuel, paper making	west and north Lu
Corn	15.43	16.50	30.86	33.00	47	fuel, fodder	west and north Lu
Rice	0.91	1.10	0.91	1.10	1	heat insulating material	central south Lu
Beat	1.27	1.60	1.91	2.41	3	fuel	whole province
Potato	3.58	3.80	3.58	3.80	5	fodder	central south Lu
Peanut	3.09	3.50	6.18	7.00	10	fodder	central south Lu, peninsula
Cotton	0.47	0.70	1.41	2.10	3	fuel	west and north Lu

In 1995, the straw and stalk output in Jinn City was: straw and stalk of wheat, 1.71 million tons; that of corn, 2.53 million tons; rice straw, 35,000 tons; rice stalk, 84,000 tons; sweet potato sprouts, 115,000 tons; beet stalk, 90,000 tons. The amount of straw and stalk as used for fodder was 1.955 million tons, which constituted 41% share of the total amount of straw and stalk in the whole province, of which, 1.31 million tons was for work animals, 0.462 million ton was for production animals, and 0.192 million ton was for sheep.

In 1995, there were 3.23 million beef cattle on hand in the demo counties for raising cows with straw and stalk, 1.13 million for sale, and 0.204 million tons for beef, which were 26%, 30%, 31%, respectively. The amount of silage ammoniated straw and stalk was 4.54 million tons, 28% of that in whole province. Cao County, Yucheng City and Huimin County are three of the "national ten best demo counties for raising cattle with straw and stalk." Cao County is a large agricultural county in flat country, with production of 1.57 million *mu* cultivated land and 1 million tons straw and stalk for fodder every year. In 1995, there were 120,000 ammoniation tanks with a volume of 240,000 m^3, 240,000 tons of ammoniated wheat straw and stalk, and 230,000 tons of corn straw and stalk silage. Of these, 60,000 tons of forage can be saved.

In 1995, the total amount of straw and stalk in Huantai County is 540,000 tons, including 140,000 tons of ammoniated straw and stalk silage, which can supply the forage for 49,000 large animals and is 18% of the total amount. The amount of straw and stalk used as production raw material in TVEs was about 50,000 tons, 9% of the total amount of the straw and stalk grew on 200,000 *mu*, was returned to the field, the amount returned to the fields was 250,000 tons, 48% of the total amount. 60,000

tons of straw and stalk was burned as fuel, 11% of the total amount. If we use Tsun as the administrative unit, the amount of the straw and stalk in Huantai County will be 1,568 tons per Tsun and the average collection radius will be 0.7 kilometers. In Huantai County, the purchasing price of wheat straw and stalk as paper-making raw material is 0.20 RMB Yuan/kg, and the purchasing price of corn core as uronic raw material is 0.40 RMB Yuan/kg.

The status of straw and stalk use in other counties and cities in 1995 is shown in Tables 8.9 and 8.10. Analysis of their use in 1995 in Shandong is shown in Table 8.11.

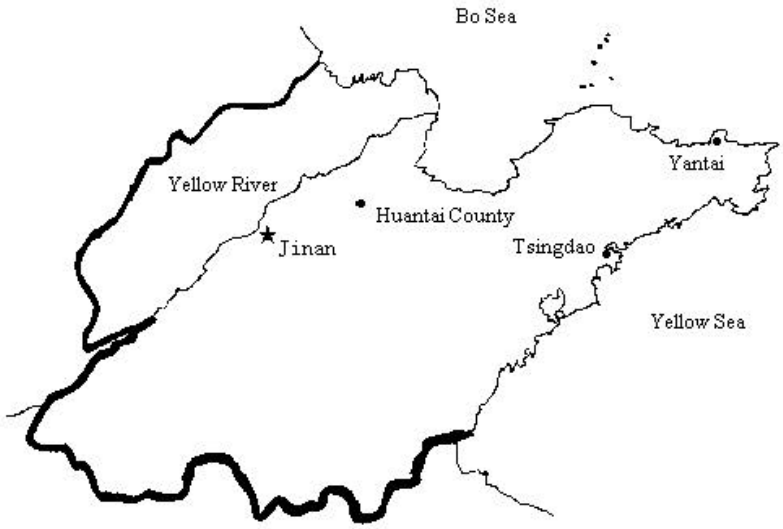


Figure 8.2 Shandong administrative region

Table 8.9 Analysis of the use of straw and stalk in other countiesand cities in 1995

(1,000 tons)

Usage	Huantai	Linzi	Changyi	Laizhou	Wenshang	Xuecheng	Junan	Wulian	Average
Total	540	400	650	870	330	340	740	430	540
Fuel	60	90	200	320	220	40	330	190	180
Forage*	100	20	160	340	50	250	380	130	180
Fertilizer *	250	160	130	200	50	30	10	40	110
Raw material*	50	40	100	10	5	10	20	30	30
Remainder	80	90	60	0	5	10	0	40	40

Table 8.10 Analysis of the percentage of straw and stalk used in other counties and cities in 1995

Usage	Huantai	Linzi	Changyi	Laizhou	Wenshang	Xuecheng	Junan	Wulian	Average
Fuel %	11	22	30	37	66	11	45	44	35
Forage* %	18	5	25	39	16	74	52	30	32
Fertilizer * %	48	40	20	23	16	8	1	10	21
Raw material * %	9	10	15	1	1	2	2	6	5
Utilization ratio %	86	77	90	100	99	95	100	90	93
Remainder ratio %	14	23	10	0	1	5	0	10	7

* Forage includes silage and ammoniation; fertilizer includes straw and stalk returned to the fields directly; raw material includes industry, construction, and agriculture.

Table 8.11 The general estimation of the use of straw and stalk in 1995 in Shandong (million tons)

Type of straw and stalk	Total amount	Burned directly	Fodder	Returned to fields	Other uses	Remainder
Total	66.50	27.40	21.60	5.20	5.70	6.60
Ratio (%)	100	41	32	8	9	10
Wheat	20.62	10.00	2.00	2.50	2.00	4.10
Corn	30.86	14.00	10.00	2.50	2.00	2.40
Cotton	1.41	1.20			0.20	0
Pachyrhiz, peanut	9.76		9.50	0.20		0.10
Soybeans	1.91	1.70	0.10		0.10	0
Rice	0.90	0.10			0.80	0
Other	1.00	0.40			0.60	0

8.3.3 Analysis on the availability of straw and stalk resource

8.3.3.1 Available amount of energy

The following conclusions can be drawn from analysis of Table 8.11: the total available amount of straw and stalk in Shandong Province in 1995 was 66.50 million tons, of which wheat and corn straw and stalk was 51.50 million tons, 78% of the total. In 1995, the use ratio of straw and stalk crops in Shandong was about 89%. There were 26.40 million tons of straw and stalk of wheat and corn that were burned directly, which was 40% of the total; 22.80 million tons of straw and stalk was used as forage, which was 34% of the total. There remained about 7.1 million tons of wheat and corn straw and stalk, which was 11% of he total.

From the viewpoint of agricultural use, most of the straw and stalk used as fuel is cotton and wheat and corn stalk. The straw and stalk of Pachyrhiz, peanut and bean is generally used as fodder. Most of the cotton stalk is used as fuel. In 1995, there were about 24.00 million tons of wheat and corn stalk used as fuel, except for 7.1

million tons of wheat and corn stalk. There is about 2.40 million tons of cotton stalk used as fuel, and 0.1 million cotton stalks left. Therefore, the available energy of straw and stalk crops in 1995 in Shandong was 33.50 million tons, for a 50% share of the total amount of straw and stalk.

As shown in Table 8.8, by the year of 2000, the total amount of the wheat, corn and cotton straw and stalk resource will be 56.60 million tons, whereas, the total amount of straw and stalk will be 71.00 million tons. According to the related plan, by 2000, the ensile ammoniated straw and stalk will hit 30.00 million tons. In light of the agricultural development plan in the Ninth Five-Year period, by 2000, the ecological agriculture area will reach 300 million mu in the whole province; by that time, the amount in straw and stalk returned to the fields should reach 15.00 million tons. At the same time, with the improvement in rural living standards, by 2000 the percentage of straw and stalk used directly as fuel will decline. It is estimated that the amount will be 25.00 million tons. Without considering the straw and stalk used in industry and other sectors, by 2000, the amount of use the above three kinds of straw and stalk will be 70.00 million tons. Remaining straw and stalk will be 10.00 million tons.

In conclusion, by 2000, the available straw and stalk amount wouldn't exceed 26.00 million tons; the actual amount used will be 25.00 million tons, or a 35% share of the total.

Straw and stalk use in 1995 and 2000 in Shandong is shown in Table 8.12.

Table 8.12 Straw and stalk use in 1995 and 2000 in Shandong (million tons)

Year	Total straw and stalk	Used as fodder	Used as frtilizer	Other uses	Energy uses	Remainder	Available for energy use
1995	66.50	21.80	5.50	5.20	26.40	7.10	33.50
2000	71.00	29.00	12.00	5.00	25.00	0.00	25.00

8.3.3.2 Energy resource distribution density

As seen in Table 8.11, the types of straw and stalk for use of energy use are wheat, corn, cotton and beans. Except for beans, the intensive output areas of these straw and stalk are west Lu, the north Lu plain, and west of Shandong Peninsula, where the amount of the resource is 75% of that in the whole province, land area is about 60%, and the total area is 72,000 km^2. According to these calculations, in 1995, the amount of wheat, corn and cotton straw and stalk in these areas was 40 million tons, and the available energy was about 25.00 million tons. Therefore, in these areas, the density of the straw and stalk was 560 tons/km^2, and the density of available energy was 350 tons/km^2.

In the same way, we can deduce that the amount of wheat, corn, and cotton will be

42.00 million tons, and the resource density of the straw and stalk in these intensive growing districts will be 580 tons/km^2 in 2000. The available straw and stalk for energy use will be 18.50 million tons, and the density of the straw and stalk for energy use will be 260 tons/km^2.

The amount, distribution density, and energy availability of the straw and stalk resource in 1995 and 2000 in Shandong Province are shown in Table 8.13.

Table 8.13 Distribution of Straw and Stalk for Energy Use in Shandong Province

Year	Resource amount (million tons)	For energy use (million tons)	Resource density (tons/km$^{2)}$	Density for energy use (tons/km^2)
1995	40.00	25.00	560	350
2000	42.00	18.50	580	260

8.3.3.3 Collection scale and radius

The average area of each administrative tsun in Shandong Province is 1.7 km^2. According to the above analysis, in 1995, in the intensive growing district of straw and stalk crops, the total amount of straw and stalk in each tsun was 950 tons (on average), available energy was 600 tons (on average), and the collection radius was about 0.74 km.

By the year 2000, the total amount of straw and stalk in each Tsun will be 1000 tons on average, available energy will be 440 tons, as shown in Table 8.14.

Table 8.14 Collection scale and radius of straw and stalk for energy use in Shandong Province

Year	Collection radius (km)	Collection scale (tons/Tsun)	
		Total	For energy use
1995	0.74	950	600
2000 forecast	0.74	1,000	440

In 1995, the total amount of the straw and stalk resource in Huantai County was 540,000 tons, and straw and stalk for energy use was 140,000 tons, representing 25% of the total. In 1995, there were 343 administrative villages in Huantai County. If calculated in the unit of administrative villages, the straw and stalk in each village in Huantai County was 1,568 tons on average; and about 400 tons were for energy use, and the average collection radius was 0.7 km. In 1995, the price of wheat stalk for raw material for paper was 0.20 Yuan/kg in Huantai county, and the price of corn core for uronic raw material was 0.40 Yuan/kg. The price of corn stalk was not clear.

CHAPTER 9 Research on the Availability of Biomass Energy in Shanghai

9.1 Introduction

Shanghai is a modernized international metropolis undergoing accelerated construction. In the metropolis there are four districts in between the downtown and the rural area: Minhang, Jiading, Baoshan, and Pudong. There are six suburban counties: Nanhui, Fengxian, Songjiang, Qingpu, Jingshan, and Chongming. The city is located on the middle coast of the East Sea, north of the delta at the mouth of Changjiang. To the south is the alluvial plain of Qiantangjiang. The city faces water in three directions and has a monsoon climate of the North Asian tropic zone, with an annual temperature of 15 . The 1995 statistics show the total area of the suburban area is 6,060.42 km^2 where the cultivated area takes up 299.6 thousand hectares (ha). The total population is 6.6479 million in 2.2847 million households. The rural population is 3.9227 million in 1.346 million households. With the evaluation of reform and the development of the expansion of our economy, the rural area has become the base for the growth of city industry, the production of non-staple foods, the development of exportation and importation, the collecting and distributing of transportation, the facility of scientific researches and the building of residential houses. This has brought fast development to different lines of work such as industry, agriculture, commerce and trade. According to the statistics in 1995, the Gross National Product of the suburban area totaled to 66.861 billion Yuan from this amount, 9.04% goes to the agricultural industry; 61.53% to the manufacturing industry, while the third industry takes up 29.43%. The development of the rural economy has resulted in the increase of farmers' income and improvement of living standards. The increase in construction of modern basic facilities and the function of the central city has especially given an impetus to the construction of basic facilities in towns and villages, and has also promoted the construction of a high-quality, high-efficiency, and convenient energy facilities such as electricity, gas and thermal energy. At present, the energy-consuming structure has been urbanized in the manufacturing industry, agriculture of the city, and the third industry as well, which entirely depends on commercial energy imported from the city for supply. While the energy consumption for daily life in the countryside has transitional from the traditional biomass energy consuming structure of using crop stalks as fuel to an entirely new structure of high-quality commodity energy consumption.

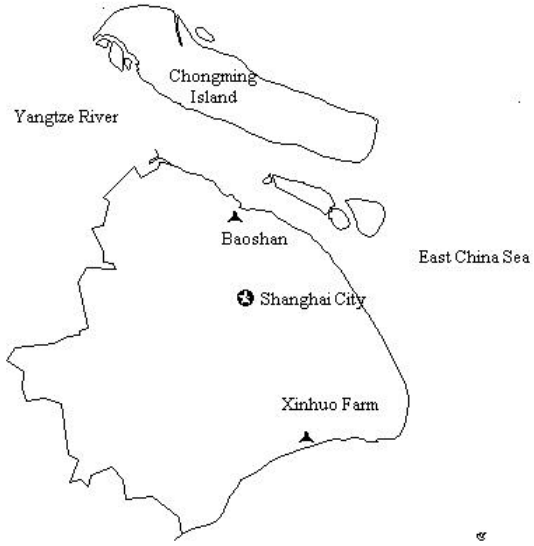


Figure 9.1 Shanghai administrative region

9.2 Analysis of the Present Situation of the Energy Consumption in Rural Shanghai

According to the statistical data from the municipal statistic bureau, the volume of energy consumption of production and living in the suburban area of Shanghai in 1995 is shown in Table 9.1. The energy consumption equals 6.0212 million tons of standard coal, which is 45.58% higher than in 1990. The consumption of such commercial energy as coal, oil, and electricity has considerably increased than in the last five years (1990) while the consumption of biological materials such as fuel wood, and crop-stalks is on the decline. This has a close relation to the improvement of the population's life-style the development of the industrial commerce, and agricultural production in the suburban area of the city in the Eighth Five-Year Plan.

Table 9.1 Energy consumption in rural Shanghai in 1995

Types of energy	Physical quantity	Standard quantity (1,000 tce)*	Types of energy	Physical quantity	Standard quantity (1,000 tce)*
Coal (1,000 tons)	3,799.0	2,713.5	Gas (1,000 m^3)	143,090	77.6
Coke (1,000 tons)	118.6	115.2	Liquefied gas (1,000 tons)	103.8	177.9
Gasoline (1,000 tons)	223.1	328.3	Heating power (TJ)	586.648	20.1
Diesel oil (1,000 tons)	172.9	251.9	Fuelwood (1,000 tons)	49.5	28.3
Kerosene (1,000 tons)	3.0	4.3	Crop-Stalk (1,000 tons)	789.0	362.9
Electricity (TWh)	4.774	1,928.7	Biogas (1,000 tons)	17,536.7	12.5

*tce = ton-coal equivalence

9.2.1 Energy consumption by sector

9.2.1.1 Energy consumption in agriculture sector

In 1995, the energy consumption in agriculture in Shanghai is shown in the Table 9.2. The total energy consumption reached 521,200 tons tce, of which, 62.18% for planting shares, and that for fishery and husbandry 16.17% and 11.82% respectively.

Table 9.2 Energy consumption for agriculture in Shanghai in 1995

Type	Coal	Gasoline	Diesel	Kerosene	Electricity	LPG*
Unit	1,000 tons	1,000 tons	1,000 tons	1,000 tons	TWh	1,000 tons
Physical quantity	13.3	6.6	119.3	0.1	0.804	1.9
Standard quantity (1,000 tce)	9.5	9.7	173.8	0.1	324.9	3.2

*LPG = Liquefied Petroleum Gas.

9.2.1.2 Energy consumption in industrial sector

The energy consumption in the industrial sector for the whole suburb in 1995 is shown in the Table 9.3. The total energy consumption is 4,037.3 thousand tce. The energy consumption in county and farms industry shares 12.89% and in town and village enterprises (TVEs) shares 48.14%. The other counties, towns, and villages enterprises shares 27.59%, the tertiary industry shares-11.38%.

Table 9.3 The energy consumption in the industry in Shanghai suburb in 1995

Type	Coal	Coke	Gasoline	Diesel	Kerosene	Electricity	Coal gas	LPG	Thermal power
Unit	1,000 tons	1,000tons	1,000 tons	1,000 tons	1,000 tons	TWh	1,000 m^3	1,000 tons	TJ
Physical quantity	3,002.2	118.6	207.2	35.3	2.3	3.326	37,090	20.0	586.648
Standard quantity (1,000 tce)	2,144.4	115.2	304.8	51.4	3.3	1,343.7	20.1	34.3	20.1

Table 9.4 The energy consumption in residential sector in the Shanghai suburb in 1995

Type	Coal	Gasoline	Diesel	Kerosene	Electricity	Coal gas	LPG	Biogas	Fuelwood	Straw and stalk
Unit	1,000 t	1,000 t	1,000 t	1,000 t	TWh	1,000 m^3	1,000 t	1,000 m^3	1,000 t	1,000 t
Physical quantity	783.5	9.3	18.3	0.6	0.644	106,000	81.9	17,536.7	49.5	789
In which:										
Towns area	582.3	1.8	1	0.1	0.307	106,000	16.5	-	-	-
Rural areas	201.2	7.5	17.3	0.5	0.337	-	65.4	17,536.7	49.5	789
Standard quantity (1,000 tce)	559.6	13.7	25.7	0.9	260.2	57.5	140.4	12.5	28.3	362.9

9.2.1.3 Energy consumption in residential sector

In 1995, the energy consumption in the suburb and rural areas in Shanghai is

1,462.700 tce. The energy consumption in the town residential living sector is 630,200 tce. The energy consumption in the farm living is 832,500 tce. Energy product types are shown in the Table 9.4.

9.2.2 Rural energy construction in Shanghai during the period of Eighth-Five Year

9.2.2.1 Extension of fuel reducing stove and coal saving stove

The statistics of 1995 show that the fuelwood reducing stoves in the suburban area are used in 1,016,900 households, which is 75.55% of the total rural households. Owing to the expanded production of coal products and increased supplying stations, the stoves in use are coal-saving. Therefore, multi-stove farm households have been in style and different forms of energy are used to compensate each other. In some parts, the fuelwood reducing stove is prepared only for contingency while coal and liquefied gas stoves are for everyday use. In practice, the use of fuelwood reducing stoves is declining and the amount of crop stalks used as fuel is only 30% of the annual yield. This brings about an increase in the burning of crop stalks to fertilize the field. To sum up, the situation of a lack of energy resources in the countryside has been greatly ameliorated.

9.2.2.2 Construction of biogas and utilization of digested slurry

As is shown in the statistics, by the end of 1995, the suburban area there has 66 concentrated biogas supplying stations with 550 digesters, of which the total volume is 43,960 m^3 with an annual yield of biogas of 11.213 million m^3 to supply 22,425 households. Seven hundred and nine household biogas digesters are newly built, the total volume of which is 5,992 m^3. The number of household biogas digesters reaches 34,903 with a total volume of 284,839 m^3 and an annual biogas yield of 6.3242 million m^3. Because of the decline in the number of animal breeding households which results in a deficiency of raw materials for biogas production, more and more household digesters are out of use or scrapped. In fact, the actual number of household digesters is 33.13% less than in 1990. With the promotion of the rural economy and the living conditions, household digesters will keep on decreasing in number.

The research and experiments on the integrated utilization and purifying treatment of the digested slurry resulted in the biogas digestion, those applica-tions that expanded are: the use of slurry in seed soaking, mixed feed for the breeding of pigs and fish, mushroom growing, production of compound fertilizer, nutritious soil, and return to field after being purified. Pollution from the drained slurry to the waters and environment is reduced accordingly.

9.2.2.3 Utilization of solar energy

At present the technology for the utilization of solar energy is maturing day by day.

During the next five-years, the stress of the utilization of solar energy is on the extension of the solar energy water heater and the expansion of construction of plastic green houses to match the construction of the "vegetable basket" project. According to the statistics, solar energy water heater amounts to 7,560 m^2 and the heater put into use in the eighth five-year plan comes to 5,760 m^2. After the establishment of the Waigang household solar energy water heater factory in the Jiading district, the sale of its product is successful. This promotes the popularization of the application of the utilization technology of solar energy. In five years, plastic greenhouses and glass hothouses have increased 15,800 *mu*, which played a positive role in the guarantee of the supply of vegetables year round to the city proper .

9.2.2.4 Rational utilization of commodity energy

With the expansion of the metropolitan area and the construction of a series of basic facilities, the difference between the energy consumption structures of the urban and rural areas is narrowing. The energy consumption structure in the adjacent suburbs and towns is approaching that of the city proper. The energy consumption structure in vast rural areas is also on its way to change from a biomass energy oriented structure to a commercial energy oriented structure. The statistics show that among the energy consumption of 6.0212 million tons in the suburban area, 5.6125 million tons are of the commercial energy of standard coal, which is 93.3% of the total energy consumption. And in the 1.4627 million tons of energy consumption in every day life, coal amounts to 38.25%, oils accounts for 28.2%, electricity makes up 17.79% and gas is 13.50%. In the entire suburban area of the city, 1.2542 million households have been using gas, liquefied gas, or biogas, which is 54.9% of the total number of the households in the entire suburban area.

9.2.2.5 Industrial snergy conservation in the suburb area

During the "Eighth-Five Year" period, The enlarging of the city and the sector restructure promote the whole industry restructure in Shanghai. Most of the TVEs grow rapidly toward the medium enterprises, who become the very important in the Shanghai economy. By the year of 1995, the gross industrial products in suburb reaches 124.063 billion Yuan. Compared with 49.211 billion Yuan in 1990, it has grown by 152.10%. And the energy consumption in industrial sector is 4.0373 million tons in the suburb area, growing by 71% compared with the energy consumption in 1990. The energy consumption per million Yuan output products reduces from 0.47 tce in 1990 to 0.33 tce in 1995. An important way is to restructure the industry, develop the industry with low pollution and low energy intensity in priority, spread the new technology for energy conservation with research and development, strengthen energy management. Moreover, the retrofitting of the industrial boiler, kiln, furnace, motor and low voltage transmission line make attribution to the energy saving, the detail energy saved by this way is 0.42 million tce.

9.3 Analysis on the Rural Energy Consumption Composition and Characteristics in Shanghai

9.3.1 Energy consumption composition

9.3.1.1 Analysis by sectors

Viewed from the energy consumption sectors, the energy consumption for industrial production holds 67.1% in the total energy consumption in the suburb area, and the energy consumption for rural and towns residential living shares 24.3%, and the energy consumption for agricultural production shares 8.6%. It is true that, since the suburb area is nearby Shanghai city, the suburb industry develops well, and the energy consumption for production shares most in the total energy consumption. Relatively, the agricultural production lies in the low level, and the energy consumption in the agricultural production shares little percentage in the total energy consumption.

9.3.1.2 Analysis by energy

Among the overall energy type consumed in the suburb area, the commercial energy consumption is 5.6175 million tce, 93.3% of the total energy consumption, biomass energy (fuelwood, straw and biogas) is 0.4037 million tce, only 6.7% of the total energy consumption. In the commercial energy, coal (including coke) holds 47.0% of the total energy consumption; oil product, 9.7%; electricity power, 32.0%; and gas (coal gas and LPG), 4.2%; Heating power; 0.4%. In the biomass energy, fuelwood shares 0.5% in the total energy consumption; straw and stalk, 6.0%; biogas, 0.2%. Compared with the situation at the end of Seventh-Five Year, the biomass energy consumption in the rural area takes on the obviously descending trend, especially the straw and stalk, whose absolute consumption reduces by 49.2% compared with that in 1990. All that is very close with the improvement of the rural economy and the farmer living standard, and the utilization of the high quality commercial energy, such as LPG.

In addition, there is very rich in solar energy and wind energy in the suburb area, especially the solar energy. In most areas, the solar energy can be utilized well, such as solar water heater, green house. As the wind energy, it can be made good use in the island area, like Chongming island. However, these renewable energy is under the pilot phase. In the long term plan, these renewable energy would make the energy utilization in the rural area step a new stage, and reduce depending on the great demand of commercial energy, mitigate the contradiction between demand and supply.

9.3.2 Energy consumption characteristics

9.3.2.1 Supply-demand analysis

The energy demand-supply in Shanghai suburb keep equilibrium basically. However, due to the energy resource shortage in Shanghai suburb, the energy consumption for production and residential living almost rely on the commercial energy from other place, therefore, the economic development and residential living improvement are restricted by the energy supply capacity of other places. For example, the supply of electricity, coal and oil couldn't meet with the demand of the suburb economy development. Every year, there exists great shortage, which results in parts of plants shutdown due to electricity, coal and oil shortage. At present, through the operation of marketing mechanism, parts shortage of coal and oil products can be resolved by the way of the plants purchase outside and market supply. However, the electricity shortage is still restricted by the electricity production and supply, the contradiction between demand and supply is very sever.

9.3.2.2 Energy consumption level analysis

According to the statistics of suburb energy consumption in 1996 and the gross industrial and agricultural production, and the population, the suburb energy consumption per million Yuan output in 1995 and per capita rural residential energy consumption are shown in the Table 9.5 and Table 9.6. In which, the industrial production includes tertiary industry and construction industry which produce the high output value products with low energy consumption, therefore, the industrial energy consumption per million Yuan output is low. But the light industry shares much in the suburb industrial structure, and there are a few of high energy intensive enterprises, and many enterprises adopt advanced technology and management, make full of the energy conservation potential. In general, the industrial energy

Table 9.5 Suburb industrial and agricultural energy consumption per million Yuan output

	Output value billion Yuan, in the 1990 price	Energy consumption (million tce)	Unit energy consumption (tce/million Yuan)
Industry	124.063	4.0373	33
Agriculture	8.722	0.5212	60
Total	123.785	4.5585	37

Table 9.6 Per capita town and rural residential energy consumption in suburb

	Population (million)	Energy consumption (million tce)	per capita energy consumption kgce/person/year)
Town	2.7252	0.6302	231.25
Rural areas	3.9227	0.8325	212.23
Total	6.6479	1.4627	220.02

consumption per million Yuan output is lower than national level. Relatively, the agricultural technology is still backward, with the situation of great input and small output, the energy consumption per million Yuan output keeps nearly same with the national average level.

With the suburb residential living energy consumption, due to the developed suburb economy in Shanghai, the farmers live a rich life. Therefore, the per capita energy consumption in both town and rural areas, are much higher than the national level, especially the commercial energy consumption, such as electricity, LPG, coal gas. And the high popularity of the all kinds of electric appliance and commercial gas in the Shanghai suburb, the per capita energy consumption ranks top in China.

9.4 Trend Analysis on the Rural Energy Consumption in the Ninth-Five Year Period in Shanghai

According to the requirement proposed by *Shanghai National Economic and Social Development in the Ninth-Five Year Plan* and the *Long Term Prospect Outline of 2010*, during the Ninth-Five Year period, the suburb industrial and agricultural structure will be restructured with large scale. After the restructure, the gross industrial and agricultural products will be improved greatly, and the people's life will step from the well-off stage toward the rich stage. Therefore, focusing on the energy consumption with the requirement of suburb economy development, the energy consumption and characteristics are described as following.

9.4.1 Agricultural sector

From the long term, agricultural production is always the weak point in the suburb economy. Compared with industry, the production lever in agriculture is very low, especially the plantation, high input and low output weaken the farmers' positiveness. During the Ninth-Five Year period, with the adjustment of the agriculture, some agricultural facility with modern level will be set up gradually, and the commercial energy consumption (electricity, coal and oil) will increase. However, due to emergence of the agricultural products with high additional value and high pay rate, the energy consumption per million Yuan output will reduce instead of increase. Additionally, the rise of tour agriculture, the retrofitting of low voltage transmission line, and adoption of oil saving technology of agricultural machine, electricity saving technology in irrigation, will reduce the energy con-sumption per million Yuan output. It is estimated that, by the end of the Ninth-Five Year Plan, the suburb agricultural energy consumption will reduce form 60 tce per million Yuan output at present to 55 tce per million Yuan output.

9.4.2 Industrial sector

In comparison with other provinces, the industrial production level in Shanghai suburb ranks the advanced place not only from technology but also on scale. However, some old equipment, backward technology and high energy intensive industry still exist. Therefore, during the Ninth-Five Year Plan, by the way of technology retrofitting, equipment replacement and industry restructure, the product-ivity and economic benefit in those industries will be improved, and the energy consumption will be reduced. In the next several years, especially the period of Ninth-Five Year, the suburb tertiary industry will grow rapidly on the present basis, and will share more percentage in the suburb economy. With the rise of the low energy intensive industry and the technology retrofitting of some high energy intensive industry, and the adjustment of the products structure, the suburb industrial energy consumption per million Yuan output will reduced to 27-30 tce.

9.4.3 Residential sector

With the development of the suburb industry and agriculture, the improvement of the urban and rural residential income, the people's living standard are improved greatly, which is now transferring from the well-off stage to the rich stage. It is estimated that, by the end of Ninth-Five Year Plan, the number of the high energy intensive electric appliance in the rural household, such as air conditioner, electric water heater will grow rapidly. On the aspect of cooking, with the improvement of housing, the existing fuelwood stove will be sorted out, and the gasification level will get more and more well. Therefore, both in town and villages, the per capita living energy consumption at the end of Ninth-Five Year Plan will increase by 10% than that at present, that is to say, the town residents reach 254.38 kgce/person.year, and rural residents reach 233.45 kgce/person.year.

9.5 Prospect on the Need for Energy in Rural Area of Shanghai in the Ninth Five Year Plan

9.5.1 Total agricultural output value in the suburban area and its need for energy in 2000

According to the agricultural development plan in Shanghai (made by the planning office of the municipal agricultural committee), the total agricultural output value in the suburban area will increase at an average rate of 3.5% a year in the Ninth Five-Year Plan, i.e., by 2000 the total agricultural output value in the suburban area will be 10.8 billion yuan (based on the fixed value as in 1990). Calculated at a rate of 5.5t standard coal/thousand yuan, the total energy need of the agricultural production in

the suburban area will be 594,000 tons of standard coal by the end of the next five-years, which will is 14.0% higher than in 1995.

9.5.2 Total industrial output value in the suburban area and its need of energy in 2000

According to the program for the development of the suburban area in the next five years (stipulated by the industry and commerce administration of the municipal agricultural committee), the total agricultural output value in the suburban area will increase at an average rate of 26.5%, i.e., by 2000 the total industrial output value in the suburban area will be 40 billion tons (based on the fixed value as in 1990). Therefore, even at a rate of 27 tons standard coal/million Yuan, the total energy need of the industrial production in the suburban area will reach 10.80 million tons standard coal, which is 2.5 times the total energy need in 1995. In other words, the energy consumption for the industrial production in the suburban area will increase at an average rate of 21.7%, the proportion of which to the production will be 1:0.82.

9.5.3 Total population in the suburban area and its energy need of everyday life in 2000

With reference to the prediction of the total population in the suburban area in "Prospect of the National Economic Development in Shanghai and the Trend of Land Development" (compiled by the National Territory Office of the municipal planning committee) by the end of the next five years, the total population in the suburban area will be 6.5 million, of which 2.9 million are town people and the other 3.6 million are farmers. The suburban countryside will be much more modernized. Thus, calculated on the assumption of 254.4 kg standard coal per capita per year for town people and 233.5 kg standard coal per capita per year for farmers, the energy need for everyday life in the suburban area in 2000 will be 1.578 million tons of standard coal, 8.0% higher than in 1995.

9.6 Prediction of the Energy Consumption Structure and Characteristics of Rural Area of Shanghai in the Ninth Five-Year Plan

9.6.1 Consumption structure

According to the above prediction, by the end of the Ninth Five-Year Plan, the total energy need in the suburban area of the city will reach 12.972 million tons standard coal, of which the energy consumption in industrial production will take up more than 80%, 15% higher than in 1995 while the proportion of energy consumption in everyday life and agricultural production in the consumption structure will have a considerable fall to about 50% of that in 1995. In view of the consumption structure

for the energy form, the proportion of commodity energy will keep rising, especially that of coal, electricity and oils. But in the everyday life, as the living conditions in the suburban rural area are improving, the traditional fuelwood or stalk ovens or stoves will be scrapped gradually. The consumption of crop-stalks and fuelwood will decrease with high quality, high efficiency and clean commercial gas as their replacement. It is a trend for the consumption of crop-stalks and fuelwood to fall in the energy consumption structure and for the consumption of commercial gas to rise.

9.6.2 Characteristics of consumption

By the end of the next five years, the total energy need in the suburban area will be more than twice that of 1995. If the present energy supply remains stable, the energy needs of everyday life and agricultural production will be basically met while the energy needs of the industrial production will be far from met. A considerably large part of the need for coal and oils must be solved by the enterprise itself. If the supplying channel in the market is smooth the energy needs of the industrial production can basically be met except that part of the production which is restricted by the electric power supply. However, as the commodity energy supply of the suburban area is almost totally imported from other provinces, once the channel is blocked (e.g., when there is a shortage of energy), some enterprises will have to stop production due to the lack of energy, which will result in a check to the economic development of the suburban area. In the long run, the energy shortage will remain a problem for the suburban area and there will be a contradiction between supply and demand.

9.7 Analysis on the Availability of Biomass Energy in Shanghai

The suburban area of Shanghai is short in mineral energy resources, but abounds in resources such as renewable biological materials (fuelwood, crop stalks, excretions of man and animals) and natural resources (solar, wind, and tidal energy).

9.7.1 Resources of Crop-Stalks

There are many resources of crop stalks from the production of grains, cotton, and edible oil. They have long been the major fuels for the country life. Calculated on the base of the yield of grain, cotton and oil in 1994, the total production of stalks is 2.0006 million tons, which is equivalent to 0.9294 million tons of standard coal. The grain stalks come to 1.7955 million tons, which is 89.75% of the total energy resources.

Table 9.7 Energy resources of crop stalks in 1994 in the suburban of Shanghai

	Grains	Edible oil	Cotton	Total
Annual yield (1,000 t)	2,244.4	95.5	4.7	
Proportion of grain to stalk	1	2	3	
Theoretical reserve of energy (1,000 t dry material)	1,795.5	191	14.1	2,000.6
Heat value (cal/kg)	3,800	3,700	3,800	
Theoretical reserve of energy (1,000 standard coal)	820.8	101.0	7.6	
Collection index	1	1	1	
Amount to be exploited (in 1,000 t dry material)	1,795.5	191.0	14.1	2,000.6
Amount to be exploited (1,000 t standard coal)	820.8	101.0	7.6	929.4

9.7.2 Resources of Animal Excrement

According to the investigation statistics on the animal breeding and their excrement in the suburban area in 1994 (provided by the environment science institution of the municipal agricultural science academy), the total amount of animal excrement in one year is up to 7.0319 million tons, that is, 2.2072 million tons when dried. The theoretical reserve of biological energy is equivalent to 1.1863 million tons of standard coal. See Table 9.8.

Table 9.8 Resources of animal excrement in the suburban area of Shanghai (1994)

	Pig	Ox	Sheep	Rabbit	Poultry	Total
Breeding (1,000 head or bird)	6,090.5	58.6	201.7	559.7	134,816.6	
Annual excrement production (1,000 t)	4,592.4	1,027.4	36.8	40.9	1,334.4	7,031.9
Dry material equivalence (1,000t)	918.4	184.9	14.7	21.7	1,067.5	2,207.2
Heat from the dry material (cal/kg)	3,000	3,300	3,700	3,700	4,500	
Theoretical energy reserve(1,000tce)	393.6	87.2	7.8	11.5	686.2	1,186.3
Collection index	1	0.6	0.6	0.6	0.6	
Index of usable heat	1	1	1	1	1	
Exploitable dry bio-material (1,000t)	918.4	110.9	8.8	13.0	640.5	
Index of biogas production from dry materials (m^3/kg)	0.30	0.20	0.24	0.24	0.36	
Amount of exploitable biogas(10^6 m)	275.52	22.18	2.11	3.12	230.58	5,333.51

It is expected that during the Ninth Five-Year Plan the amount of animal breeding by farmers in the suburban area will decrease with the betterment of their living conditions and economic level. The breeding on the large and middle-sized animal farms will further develop to ensure a fair self-sufficient rate. So it is anticipated that animal excrement resources in the near future will remain at the present level. Unfortunately, the animal excrement used in the anaerobic digestion in the suburban area only come to around 150,000 tons, i.e., 2.1% of the total amount. The rest of the animal excrement is directly applied to the field in the conventional way, which

results in serious pollution to the environment.

9.7.3 Solar energy resources

The solar energy has been listed in the major new energy resources to be utilized all over the world in the future. The suburban area of Shanghai is at 31.45° north latitude and 121.29° east longitude with an average annual temperature of 15.7 . According to the meteorological statistical data from 1958 to 1980, the average annual sunshine is 2,014 hours and the insolation rate is 54%. The average annual solar radiation is 111.59 cal/cm^2. It can be seen that the area is in such a situation that the solar energy resource can be exploited. The distribution feature is that the north suburb Baoshan is the most abundant in sunshine with an average annual sunshine time of 2,234 hours and solar radiation of 118.44 cal./cm^2. By now 7,560 m^2 solar energy heaters have been put into use and plastic greenhouses of more than 80,000 *mu* have been built. Still the utilization of the resource is small and some plan should be made to further exploit and make use of the resource.

9.7.4 Wind energy resource

The utilization of wind energy resource has caught the attention of the whole world. The suburban area of Shanghai is located at the mouth of Changjiang and on the coast of the East Sea with an altitude of about 4-5 m where the East Asian monsoon is prevailing. The average annual wind rate is 2.8-4.5 m/sec with 3.5-4.5 m/sec at its highest in spring from March to April. The annual effective wind time is between 3,143-4,317 hours. The density of effective wind energy is 74-127 W/m^2 and the annual effective wind energy is 400-800 kW/m^2. It is one of the areas in the southeast coast of our country, which is rich in wind energy resource, it has a brilliant prospect to further construct wind energy utilization facilities so as to make better use of the isles and marshes on the coast.

To sum up, there is a sufficient supply of biological materials in the suburban area of Shanghai. Take crop-stalks as an example, the annual production of crop-stalks is as high as 2 million tons while the actual consumption (used as fuel) is less than 40% of the production. So, different uses of crop-stalks to increase the utilization efficiency will not only alleviate the lack of commodity energy in the suburban area, but also make a full use of the energy resource in the biological materials. The area is also abundant in resources of animal excrement. About 7 million tons of animal excrement are produced every year. Presently, only about 0.15 million tons of the animal excrement are used in anaerobic digestion for the production of biogas. If we devote major efforts to the development of environment protection energy projects (biogas fermentation) to match the projects of the animal excrement pollution control on large and middle-sized animal farms in the suburban area, not only the problem of pollution will be solved, but the lack of fuel for life in the suburban area will be

alleviated with the large amount of biogas from the biological materials. Thus we can see it has a rather brilliant prospect.

Moreover, the area is also considerably rich in solar energy and wind energy. Solar energy is especially appropriate to be utilized in most of the suburban area, e.g., solar energy heaters, sunshine greenhouses, and so on while wind energy can be utilized on isles and coasts in line with local conditions. The exploitation and utilization of these energy resources are still in preparation. In a long run, they will not only help to take a new step forward towards the utilization of energy resources in the suburban area, but also alleviate the contradiction of supply and demand to some degree.

9.8 Conclusion

As economy develops and technology progresses, high energy consumption level continues from area, and production increases where commercial energy accounts for the largest part of energy supply, and the contradiction between supply and demand deteriorates with economic development; we should do our best to consolidate our present metropolitan construction, update our ideology for innovation, depend on scientific technology to improve our management, exert more efforts to fully exploit and utilize resources of renewable energy to have a better energy consumption and high consumption efficiency to alleviate the insufficient energy supply. All in all, we should do everything to conform to the general trend of the change in the energy consumption structure. And at the same time, energy resources should be utilized at different levels through energy conversion and suitable utilization technology for a united and harmonious development in energetic, economic, and ecological benefits so as to suit the needs of an international metropolis in the 21st century to insure high quality of energy and environment for its suburban area.

For these reasons, during the Ninth Five-Year Plan the exploitation and utilization of renewable energy resources and new energy resources will be stressed while the utilization of commodity energy is improved. This measure not only provides a supplement to the recent energy shortage, but also lays a foundation for the future energy structure. Therefore, we should have our eyes on the 21st century when considering the technology, size, standard and comprehensive benefits for the energy structure.

The present ecological environment in the suburban area of Shanghai is poorly matched with the economic construction level. The concentrated expression of it lies in daily production of large amounts of animal excrement on large and middle-sized farms that are straining the environment for lack of a treatment or suitable utilization. Fuelwood and crop-stalks scatter everywhere to pollute the environment because of

the popularization of commercial gas. This situation not only brings about a waste of energy resources and environment pollution, but also is quite out of tune with the construction of an international metropolis. During the next five-years the solution of energy shortage in the suburban area should not be limited to the energy shortage itself, but organically united with the environment protection and the overall development in the suburban area. Exertion should be made to extend energy environment projects that will not only produce energy, but also control environment pollution such as anaerobic digestion projects treating animal excrement. High level resource utilizing technology should be studied to better use the resources of crop-stalks and fuelwood, for instance, the gasification of stalks and the manufacture of light construction material. Only in this way can we improve the present environment pollution in the suburban area. Different resources of biological materials should be fully exploited. The potentials in solar energy, wind energy, and energy saving tactics should be tapped so as to make a full use of the rare resources and alleviate the shortage of commercial energy in the suburban area.

During the next five-years, at the exploitation and utilization of renewable energy and new energy are conducted for rural energy consumption, an urbanized rural energy industry and market should be established to suit the energy consumption and supply structure under a market economy system utmost.

Note: As commodity energy circulation is open, statistic data can never be fully collected. The quoted data are for reference only.

Weights and Measures

1 ton of coal=0.7143 tce, average
1 *mu* = 1/15 hectare
Kilo=10^3, Mega=10^6, Giga=10^9, Tera=10^{12}

Abbrevation and Acronyms

kW	-kilowatt
kWh	-kilowatt-hour
GWh	-gigawatt-hour
TWh	-terawatt-hour
t,ton	-metric ton
tce	-ton of coal equivalent
LPG	-liquified petroleum gas
GDP	-gross domestic product
BRDB	-Biomass Resource Database
RMB	-Renminbi

Terms

collection radius	-The radius of collecting straw
four-side woods	-The trees around residential house
compost	-A mixture of decaying organic matter, as from leaves and manure, used to improve soil structure and provide nutrients.
Renminbi (RMB)	-An exchange rate for the unit of Chinese currency called Yuan. As of June 10, 1998, 8.28 Yuan = 1 U.S. dollar.

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