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ENERGY PLANNING AND MANAGEMENT IN NINGNAN COUNTY, CHINA

A CASE STUDY

Huang Zhijie

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PREFACE

A programme on 'Strengthening Rural Energy Planning and Management in the Mountain Districts of the Hindu Kush-Himalayan Region' was organised during the period from January 1987 to November 1988, funded by the European Economic Community. Various activities were implemented under this programme. Six case studies, relating to 'Energy Management and Planning', covering five regional countries (Bhutan, China, India-2, Nepal, and Pakistan) were also conducted. These case studies provided inputs to develop energy management and to plan guidelines that could be used for training district level officers working in the field of energy-related issues. Dr. Ganesh Bahadur Thapa, a consultant, reviewed and improved the presentation of these six case studies.

This study is one among these six case studies and was conducted in Ningnan County, situated in the south of the Sichuan Province of China. It analyses the energy situation of Ningnan County and suggests alternative ways for the efficient use of existing energy sources.

Wind Energy
Geothermal Energy

Energy Consumption Patterns in Ningnan County

The Energy Demand Forecast in Ningnan County

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LIST OF ABBREVIATIONS

TOE	=	Tons of Oil Equivalent
Mu	=	Area measurement approximately equal to 0.067 ha
Xiang	=	Administrative division of a county comprising of several villages

Energy Content and Conversion Factors

	Natural Units	kcal ('000)	TCE	TOE	Others
Non-commercial					
Fuelwood	ton	4,000	0.57	0.39	1.43 m ³
	m ³	2,800	0.40	0.27	700 kg
Dried Dungcake	ton	2,600	0.37	0.25	—
Agricultural Residues	ton	3,000	0.43	0.29	—
Commercial Fuels					
Diesel	kl	9,080	1.29	0.88	0.826 ton
	ton	10,960	1.57	1.07	1,210 litre
Light Diesel Oil	kl	9,350	1.34	0.91	0.853 ton
	ton	10,960	1.57	1.07	1,172 litre
Petrol	kl	8,000	1.14	0.78	0.709 ton
	ton	11,290	1.61	1.10	1,411 litre
Kerosene	kl	8,660	1.24	0.84	0.778 ton
	ton	11,130	1.59	1.08	1,285 litre
Liquefied Petroleum Gas	ton	11,760	1.68	1.14	—
Coal	ton	6,000	0.86	0.59	—
Electricity	MWh	860	0.12286	0.083576	—
Other Conversion Factors					
1 TCE			1.00	0.680272	
1 TOE			1.47	1.00	

Heat Content of Different Fuel Types

1 kg wood	=	15 MegaJoules (MJ)
1 kg coal	=	26.5 MJ
1 litre of kerosene	=	43.6 MJ
1 kWh of electricity	=	3.57 MJ

Background

Energy plays a crucial role in the socioeconomic development of any country. As witnessed by the history of human society, economic growth requires an increase in the quantity of energy consumed. This is because increase in industrial and agricultural production results in a corresponding increase in energy consumption. That is why in the developed countries of Europe, and in Australia and Japan, the average per capita annual energy consumption is about 4 to 5 tons of oil equivalent. In North America the quantity is even greater. Developed countries with one quarter of the world's population consume 4/5th of the world's total commercial energy consumption, whereas in most developing countries the average per capita annual commercial energy consumption is less than 0.2 ton of oil equivalent. In recent years, energy consumption in China increased very rapidly. In 1983, with an average per capita energy consumption of 455 kg of oil equivalent, China ranked 69th among 126 countries.

While some countries depend excessively upon fossil fuel to meet their energy needs, others still fall back upon forests and other traditional forms of energy. For developing countries the energy problem has various implications. Most of the population of the developing countries live in rural areas. Their per capita energy consumption is very low. The energy consumed is mainly biomass energy, such as fuelwood and agricultural waste, and very little commercial energy is used in these countries. In many countries the consumption of firewood has exceeded the growth rate of wood. As a result, each farm household must spend more time and labour to find firewood further away from home. Because of the inadequacy of stalks and firewood for meeting energy needs, people now turn to the use of animal manure for fuel, thus depriving the soil of the nutrients needed for plants. This has continued to adversely affect agricultural productivity.

The above scenario fits into most of the rural areas of developing countries, including Ningnan County in China. In this case study an attempt has been made to examine the energy scene in the county and explore possibilities for promoting alternatives to reduce the dependance of the county on the fragile environment.

Objectives of the Study

The overall objective of the study is to analyse the energy situation of Ningnan County and suggest alternative ways for the efficient use of existing energy sources. The specific objectives are given below:

1. To analyse energy problems in the county and to estimate energy potential by source.
2. To assess energy consumption and to forecast energy demand in the county.
3. To suggest an energy planning and implementation programme for the county for the efficient use of energy resources.

Methodology

The case study is largely based on secondary data. Information on population, land use patterns, social infrastructure, livestock holdings, and physical resources have been collected from secondary sources. Official statistics regarding commercial energy supply and consumption have also been used.

Because of the diversity in energy consumption patterns, separate forecasts are made for intermediate energy demand and household energy demand. The forecast for household energy demand is based on the size of the rural population and on average per capita consumption.

Introduction to Ningnan County

Ningnan County is situated in the south of the Sichuan Province of China. The county is located between 102° 7' 44" and 102° 55' 9" longitude east and 26° 50' 44" and 27° 18' 24" latitude north. The county is 52 km from the south end to the north end and 43.5 km from the east to the west. The total area of the county is 1,674.93 km².

With the Hengduan Mountain Range across the county from south to north, the county belongs to the high mountain area. The highest mountain is the Beimu Mountain with an elevation of 3,919 m. The lowest part of the county is the Jinshajiang River Valley with an elevation of 585 m. The county mostly consists of mountain and deep valley areas. The banks of the river valleys are the main cultivable areas of the county and cover about 10 per cent of the total land area.

The county has a total land area of 2.5 million *Mu*¹. Of the total land, 222 thousand *Mu* (th *Mu*) or 8 per cent is cultivated. The forest area covers 1,546 th *Mu*, which is 61.6 per cent of the total area. The rest of the area includes areas used for animal husbandry, rivers, reservoirs and fish ponds, and residential areas.

Among the land areas classified as forests, only 39 per cent is forest-covered land. As shown in Table 1, as much as 32 per cent of the forest area consists of uncultivated mountains and is suitable for afforestation. The remaining area includes thinly scattered forests, bushes, and newly afforested areas.

About 88 per cent of the forest-covered land in this county is located above 1,500 m and includes, for the most part, timber forests and shelter forests. The rest of the forest area, lower than 1,500 m, includes economic forests and fuel forests. With an increasing population more hillside fields are used for cultivation, thus damaging the fragile ecological balance. As a result of rapid deforestation, the soil erosion rate is increasing and unusual changes in the climate are frequent.

The county has 24 *xiangs*, 10 villages, and 840 farmer groups with a total population of 143,781. Of the total population, 93 per cent (133,777) is rural. The population density is 85.8 per km². The county is multi-ethnic. The ethnic groups living in the county include *Han*, *Yi*, *Hui*, *Miao*, *Zang*, and others.

The climate of the county is subtropical. In the most densely populated areas which lie below 1,300m, the average temperature throughout the year ranges from 18° to 19° C.

The pig is the main domestic animal raised. In 1986, the county had 136.8 thousand pigs. However, the population of herbivorous animals is relatively low in the county. In the same year, the county had 21 thousand cattle, 10 thousand water buffalo, 1,550 horses, and 89 thousand sheep. The county has only 636 th *Mu* of natural grassland and 634 th *Mu* of forest grassland. If the grassy areas can be improved upon the number of cattle and other animals can be increased.

¹ 1 *Mu* = 0.67 ha

Table 1: The Land Use Pattern for Forestry and the Forest Resources in Ningnan County

Forest Type	Land Area (th <i>Mu</i>)	Percentage of Land Area (%)	Forest Resources (Thousand m ³)
1. Total forest-covered land	602.0	39	-
- Timber forest	204.7	-	655.2
- Economic forest	111.8	-	-
- Shelter-forest	203.3	-	650.6
- Bamboo forest	18.4	-	-
- Fuel forest	68.8	-	204.1
2. Uncultivated land	405.1	32.0	-
3. Spare woods	279.7	18.1	-
4. Bush forest	167.2	10.8	-
5. Newly afforested land	2.2	0.1	-
6. "Four side" trees	1.8213 million		

The industry of the county includes agro-processing units and small hydropower generating units. The county had 76 enterprises with a total output value of 34.45 million *yuan* as of 1986. Sugar, raw silk, cement, and were the main products of those enterprises. The hydropower units generated a total of 10.21 kWh electricity in 1986. The value of agricultural output was 44.95 million *yuan*, while the gross total value of agricultural and industrial output was 79.4 million *yuan* in 1986.

The Energy Resources in Ningnan County

According to the data acquired from geological surveys, there are very few fossil energy resources in Ningnan County. The proven coal reserve is 1 million tons, but the quality of coal is very poor. Hence, the coal mine was closed in 1962 and the coal needs of the county are fulfilled by imports from Hulli County. The oil products consumed in the county are supplied by the commercial departments and are based on the State Plan. The energy resources that can be locally developed and used are hydropower, biomass energy, solar energy, wind energy, and geothermal energy.

Hydropower

The main rivers in Ningnan County are the Jinshajiang River, one of the main tributaries of the Changjiang River, and the Heishul River, one of the tributaries of the Jinshajiang River. Apart from the two main rivers there are 122 small rivers contributing to the abundant hydro potential. The theoretical hydro potential of the county is 382.5 thousand kW as shown in Table 2, while the distribution of existing hydropower stations is shown in Table 3. The hydropower potential of the county is 73.2 thousand kW or 509 W per capita. The hydro potential of all rivers is given in Table 2. Because the water source of the rivers is natural precipitation, the distribution of the runoff follows the distribution of precipitation. Since the county has distinct wet and dry seasons, the precipitation distribution is very uneven within the year. From May to October the rainfall is abundant, hence, the precipitation during this season is 91 per cent of the annual total, whereas from November to April the precipitation is low and accounts for only 9 per cent of the total. The water flow of the rivers in different months is also very uneven. The water flow in July is about 9 to 10 times that of those in March, April, and May. Such river characteristics make the full use of hydro potential very difficult.

Firewood

The natural environment for development of the forests is favourable in Ningnan County. However, because of the overfelling of trees in the past a substantial part of the forest area has been destroyed. Currently, a large area of the high hillside slopes has been converted into cultivated land. In general, both the area of forest-covered land and the amount of firewood that can be harvested rationally have been reduced. At present, the amount of firewood that can be harvested rationally is 67.4 thousand tons per year or 469 kg per capita as shown in Table 4.

Table 2: The Hydropower Potential of the Rivers in Ningnan County

Name of Rivers	River Length (km)	River Drop (m)	Average Flow (multi-year) (Cubic m/s)	Theoretical Reserves (thousand kW)	Developable Reserves (thousand kW)	Stations & Capacity	
						Number	Capacity (kW)
Heishui	59	460	6.82	290.7	52.4	36	718.6
Biji	36.3	2700	5.02	23.4	3.6	42	574.3
Jule	18.75	2450	2.24	9.0	2.2	10	160
Longdong	17.0	2030	3.34	18.4	1.2	16	543
Shancha	20.7	1750	1.62	7.6	3.3	5	135
Yibu	20.5	2550	1.01	6.2	4.1	2	199
Zhllu	19.0	1250	1.00	4.9	1.2	7	547
Xiaohe	19.2	2350	1.83	10.5	0.8	21	351
Yinchang	13.6	1500	0.59	2.5	1.7	8	1082
Qiluogou	15.4	1650	0.53	2.3	0.6	18	192
Gualiugou	12.0	2140	0.42	3.4	0.7	11	130
Laomu	10.0	1350	0.34	2.1	1.2	10	116
Yiebigou	9.7	1150	0.41	1.5	0.2	8	20
Total				382.5	73.2	193	4767.9

Table 3: The Distribution of the Hydropower Stations in Ningnan County as of 1986

Name of Xiang	Number of Stations	Capacity (kW)	Electricity Generated in 1986 (kWh)
1. County-owned stations	4	940	3820
2. Pihui	10	600.8	1667.8
3. Jingxing	4	52	34.9
4. Jule	10	164	110
5. Shili	27	299.3	201
6. Shanshu	3	50	33.6
7. Songlin	4	60	40.3
8. Xinhua	5	54	33.6
9. Shuangtang	5	60	40.3
10. Liangzi	3	40	26.3
11. Xiyao	3	97	65.1
12. Datong	15	169	113.2
13. Hongxing	1	125	600
14. Huatan	4	450	667.1
15. Qiluogou	18	195	130.9
16. Paoma	13	199	133
17. Gouge	4	45	30.2
18. Liucheng	20	212	74.2
19. Xingfu	24	253.5	237
20. Haizi	5	72	48.3
21. Songxin	13	415	979.9
22. Daogu	2	46	30.9
23. Liutie	1	75	50.3
24. Xincun	9	150	100.7
25. Xinjian	3	72	48.3
Total	198	4966	9320

Table 4: Firewood that can be Harvested Rationally in Ningnan County

Forest Species	Areas of Forest (th <i>Mu</i>) Harvested	Proportion of Area from which Firewood can be Obtained	Annual Firewood Output Per <i>Mu</i> (kg)	Annual Firewood Output (Thousand Tons)
Firewood forest	63.7	1	500	31.9
Timber forest	204.7	0.5	50	5.1
Shelter forest	203.3	0.2	25	1.0
Sparse woods	279.7	0.4	50	5.5
Bush forest	167.2	0.4	90	5.9
"Four side" trees	1.82 million trees	1	2 kg/tree	3.6
Mulberry	9.60 million trees	1	1.5 kg/tree	14.4
Total				67.4

Biomass Energy

Crop stems constitute the most important by-product of agricultural production and are main source of the daily supply of energy in rural households. In the river valley areas of the county, where the farmers are mainly engaged in cultivation, the biomass supply is quite abundant. If the ratio of crop stem output to the grain output is calculated, the total crop stem output in 1985 would be 83.4 thousand tons, which is equal to 28.8 thousand tons of oil equivalent (TOE). In addition to that, the county also produced 220 thousand tons of bagasse in 1985, some of which was used as raw material for fibreboard production.

Based on the livestock population in 1985, the total manure collected was 58.3 thousand tons (Table 5). In addition to the manure of cattle and sheep, which can be directly used as fuel, the county also had 32.6 thousand tons of pig manure which can be used as raw material for biogas. Besides, on the uncultivated mountains and hillside fields, about 20 thousand tons of grass can be harvested, and this also could be used as fuel.

Solar Energy

Sichuan is one of the cloudy provinces in China. For example, in Chengdu City the annual sunshine duration is less than 1,400 hours. However, the sunshine duration and solar radiation in Ningnan County, which is located in the southern mountain area of Sichuan, are relatively high. The multi-year average sunshine duration is 2,454 hours and the minimum sunshine duration is 2,041 hours per year. The sunshine duration is maximum in March and April and minimum in June and September. The multi-year sunshine duration, sunshine percentage, and solar radiation are given in Table 6. The sunshine percentage in Ningnan is 51 per cent and the average annual radiation is 127.4 kcal per cm². Among the five classes of China's solar energy resource regions, Ningnan belongs to the third class of areas, having moderate solar energy resources.

Table 5: The Human and Animal Manure Resources in Ningnan, as of 1985

Source Number	Manure	Collection Produced (ton)	Real Amount Coefficient	Collected (ton)	Calorific value Energy (kcal/kg)	Equivalent (TOE)
Human	142269	3116	0.8	2493	4500	1222
Cattle	30238	39733	0.5	19867	3300	6556
Horse	1439	1970	0.5	985	3700	365
Mule	6	8	0.5	4	3700	2
Pig	136210	39733	0.8	31818	3000	9546
Sheep	89056	6501	0.5	3251	3700	1203
Chicken	167427	4889	0.5	2445	4500	1100
Duck	2087	61	0.5	314	4500	14
Goose	239	7	0.5	4	4500	2
Rabbit	560	8	0.8	7	3700	2

Table 6: Multi-year Average Monthly Sunshine Time, Sunshine Percentage, and Solar Radiation in Ningnan County

Month	Average Sunshine Time (H)	Average Sunshine Percentage (%)	Solar Radiation (kcal/cm ²)
January	210	64	8.9
February	203.3	64	9.6
March	248.7	67	13.2
April	239.3	62	13.8
May	205.2	49	13.1
June	135.4	33	10.3
July	173.7	41	11.8
August	188.8	47	12.2
September	138.5	33	9.4
October	145.9	41	8.6
November	176.1	54	8.2
December	203.7	63	8.9
Annual	2257.7	51	127.4

Wind Energy

Because of the diverse topography of the county the wind resources vary tremendously. In the densely populated areas, the wind speed is low. Only in the Jinshajiang River Valley and the Heishui River Valley, is the wind speed faster than 3 metres per second (m/s) for about 1,000 hours per year. At the intersection of the Jinshajiang River and the Heishui River the wind speed is faster than 3 m/s for about 3,000 hours per year. On the top of the high mountains wind speed is generally high. Hence, the wind resources of these areas may be worth developing.

Geothermal Energy

Geothermal energy has been found in five locations in the county where the average temperature is generally above 50° C. A few of them have an average temperature of more than 80°C. However, none of them has been developed because of the remoteness of their locations.

Excluding the energy resources that are at an early stage of research and development, such as solar energy, wind energy, and geothermal energy, other natural energy resources are summarised in Table 7. The per capita natural energy resource in Ningnan County is 1.058 TOE.

Table 7 : Natural Energy Resources in Ningnan County

Energy Resources	Amount in (thousand T)	Amount in thousand TOE	Percentage (%)
1. Hydropower	0.22 billion kWh	66	43.8
2. Crop Stems	83.4	28.8	19.2
3. Firewood	67.4	27.0	18.0
4. Grasses	26.0	8.8	5.8
5. Human and Animal Manures	61.3	20.0	13.2
Total		150.6	100

Note: The calorific values of the energy sources are as follows:

Crop stems and grasses	: 3400 kcal/kg;
Firewood	: 4000 kcal/kg;
Manure	: 4250 kcal/kg;
Electricity	: 3000 kcal/kWh.

In terms of biomass energy resources, Ningnan County can be divided into four zones. Zone one is mainly located along the banks of the Heishui River and the Jinshajiang River, with an elevation of lower than 1,300 m. It is the most densely populated rural area of the county, with 49.6 per cent of the total population, but it only has 20.8 per cent of the total land area. This zone is seriously deficient in fuel but the conditions for developing biogas are ideal.

The second zone lies in the middle mountain area above the river valley, and at an elevation between 1,300 to 1,800 m. It accounts for 27 per cent of the total land area and 31 per cent of the total population. This is a favourable area for developing forestry. This zone is also generally deficient in energy. In particular, households with insufficient labour and poor agricultural production cannot meet their fuel needs.

Zone three constitutes the upper part of the middle mountain area between 1,800 to 2,000 m. The shares of this zone in the total land area and population of the county are 28 per cent and 16 per cent respectively. This zone, which is suitable for developing forestry, is self-sufficient in fuel.

Since the fourth zone is very sparsely populated, per capita energy availability is the highest in this zone. The biomass energy resources of all four zones are shown in Table 8.

Energy Consumption Patterns in Ningnan County

The commercial energy consumption in the county mainly includes coal, electric power, gasoline, kerosene, diesel oil, and coke. In 1986, the total commercial energy consumption in the county was 14 thousand TOE (Table 9). Apart from electricity, the entire commercial energy consumed in the county is supplied externally.

Commercial energy is consumed mainly in the production sector. The sector consumes about 12.1 thousand TOE or 86.4 per cent of the total commercial energy consumption. Only 13.6 per cent of the commercial energy is consumed in daily household use. Electricity is the main commercial energy consumed in the households for lighting and to operate domestic appliances. In the past, power supply in the urban areas was not sufficient and power supplies to the factories were rationed. However, after the operation of the 2600 kW unit from Laomuhe Power Station, the ration system has been discontinued. Coal is used for cooking in urban households with relatively high incomes. In the areas where electricity is not supplied, kerosene is used for lighting.

Coal and electricity are the main energy sources used in the industrial sector, constituting about 85 per cent of the total consumption of the sector. Diesel oil is used in tractors, in diesel engines, and for water pumps in areas where electricity is not available. It is also used for agro-processing, and power generation in some rural areas. Oil products are supplied by the Government according to the annual plan. Hence, the supply of gasoline and diesel is limited. Oil supplies are based on the number, capacity, and operation time of the equipment consuming oil. Coal is supplied to urban residents and farmers cultivating cash crops at a government-determined price which is normally subsidised. Commercial energy is managed by government undertakings such as the Fuel Company and the Electric Power Company.

Table 8: The Biomass Energy Resources of the Energy Zones in Ningnan County
(in Tons)

	Zone 1	Zone 2	Zone 3	Zone 4
Grain and oil crop stems	26935	21870	12085	1110
Sugarcane leaves	10633	219	-	-
Grasses	10450	4600	6100	3700
Mulberry branches	10620	3780	-	-
Timber forest firewood	88.6	975.4	2925.6	1129
Shelter forest firewood	20.3	440.8	632.2	4448.2
Fuel forest firewood	1092.5	16796.5	13657	341.5
Bush forest firewood	5.6	1296.4	2888	1829.4
Sparse wood firewood	66.4	1103.6	2414.4	201
Total in TOE	21100.5	13891.3	15250.8	3645.0
<hr/>				
Population (person)	64742	42458	21047	2357
<hr/>				
Capita availability in TOE	0.3239	0.4435	0.7246	1.5337
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Total, excluding grain crop stems in TOE	11942.6	11395.5	11141.9	3237.6
<hr/>				
Capita availability, excluding grain crop stems in TOE	0.1845	0.2684	0.5294	1.3736

Note: Calorific value of the biomass energy sources are the same as in Table 7.

The non-commercial energy sources include firewood, crop stems, grasses, and bagasse. The total non-commercial energy consumption in Ningnan County is 50.2 thousand TOE per year, constituting 78 per cent of the total energy consumption. The household sector consumes a total of 42.6 thousand TOE or 84.9 per cent of the total non-commercial energy supply. Only 15.1 per cent of the total non-commercial energy is used in the industrial sector. A large quantity of bagasse is used in sugar refineries and some is used in the production of fibreboard. Firewood is used to dry tobacco and to produce bricks and tiles.

In 1985 energy consumption in the household sector was 44,600 TOE or roughly 69 per cent of the total energy consumption in the county. This is because the industrial sector was not well developed and energy needs in the agricultural sector were mostly met by human and animal labour. The energy consumption of the agricultural sector was 1,900 TOE or about 3 per cent of the total energy consumption in 1985.

Table 9: Commercial and Non-commercial Energy Consumption in Ningnan County

Energy Sources	Annual Consumption (tons)	Annual Consumption (in TOE)	Percentage (%)	Consumption Used in Production Sector	Consumption Used in Domestic Sector
Commercial Energy:					
Coal	16506	8253	58.8	7420.5	832.5
Electricity	12.69 MkWh	3807	27.2	2905.5	901.5
Gasoline	1181	1181	8.4	1181	
Kerosene	179	179	1.3		179
Diesel Oil	547	547	3.9	547	
Coke	75	52.5	0.4	52.5	
Total		14019.5	100	12106.5	1913
Non-commercial Energy:					
Firewood	51928	20771.2	41.3	817.6	19953.6
Crop stems	40012	13604.1	27.1		13604.1
Grasses	25964	8827.8	17.6		8827.8
Bagasse	1991	6772.5	3.5	6772.5	
Biogas	520 thousand m ³	260	0.5		260
Total		50235.6	100	7590.1	42645.5
Total consumption		64255.1		19696.6	44558.5

Note: The calorific values of the energy sources are as follows:

Coal : 5000 kcal/kg
Coke : 7000 kcal/kg

The share of non-commercial energy sources, particularly biomass energy, is very high in the total energy consumption. In 1985, biomass energy constituted roughly 96 per cent of the energy consumed in the household sector. Firewood alone constituted about 46 per cent of the total household energy consumption. Although the present level of household energy consumption can be met by the existing forests, the exploitation of forest resources is not carried out in a rational manner. Under these circumstances, the current level of firewood consumption should be reduced in any effort to solve the rural energy problem. Moreover, the present use of biomass energy is low in efficiency because of substantial wastage. This calls for greater attention in developing and popularising energy saving techniques. In addition, the development and use of new energy sources, including biogas, should be promoted.

Per capita consumption of energy, particularly commercial energy, is very low in Ningnan County. The annual per capita energy consumption in the county in 1985 was 452 kg of oil equivalent, about 60 per cent of the national average. Moreover, the annual per capita consumption of commercial energy was only 100 kg of oil equivalent or about 18 per cent of the national average. The major problems related to energy consumption in the county are discussed below.

1. Low Energy Use Efficiency. About 3/4th of the energy consumed in the county is biomass energy, and nearly all the biomass energy is burned directly in the traditional rural Chinese stoves. These stoves generally have the thermal efficiency of only 10 per cent. Hence, apart from being a health hazard, these stoves waste a lot of energy. In Sichuan Province, 130 stoves were tested for thermal efficiency. The efficiency level estimated was between 9.87 to 10.66 per cent. In the industrial sector, firewood is used for drying tobacco and producing bricks and tiles. Because the equipment used is out dated, the thermal efficiency in this sector is also very low.
2. High Firewood Consumption Rate. The annual firewood consumption rate in the county is more than 50 thousand tons. In addition, 8,000 cubic metres of timber is felled every year. Thus, the annual felling of firewood and timber is much more than the rationally permissible limit.
3. Lack of Alternative Energy Resources. The hydropower output is not reliable enough to guarantee a steady supply. Despite a vast theoretical potential, the investment required to harness this source is considerable. The existing hydro systems lack reservoir regulation capacities and this results in uneven energy generation depending on the river flow. In Ningnan, there is no fossil energy reserve which can be developed economically. The coal and oil products required for the county are supplied from external sources.

The Energy Demand Forecast in Ningnan County

According to the requirement of the Seventh Five Year Plan (1985-1990) and the economic development planning for 2000, the energy planning in Ningnan is expected to follow the strategies outlined below.

- Initiation of the process of conversion of the largely self-sufficient agricultural economy into a commercial economy.
- Development of agriculture and animal husbandry in the short term, processing industries in the medium term, and forestry in the long term.

- Gradual reduction in the use of biomass.
- Develop hydropower electricity and other new technologies such as solar energy, wind energy, and geothermal energy.

Based on the natural resource potentials of Ningnan, several agro-products, such as silk, sugarcane, fruits, tobacco leaves, live pigs, tung oil trees, and timber, have tremendous export potential. The export of these commodities should be expanded in order to meet the ever-increasing cost of fossil fuel import. In addition, agro-processing industries based on locally-produced agricultural commodities should be developed. Table 10 gives the scope for economic development in Ningnan from 1990 to 2000.

Table 10: Scope of Economic Development in Ningnan County in 1990 and 2000

	Unit	1930	1990	2000
Industrial output value	10 thousand yuan	2520	5396	11000
Agricultural output value	10 thousand yuan	4957	6859	9000
Gross output value of Industry and agriculture	10 thousand yuan	7477	12255	20000
Population	10 thousand yuan	14.2	15	16.5
Grain production	ton	62275	65505	69350
Sugarcane production	ton	140000	272000	290000
Flue-cured tobacco	ton	500	1250	2250
Mandarin orange	ton	165	5200	8000
Banana production	ton	150	3000	6000
Mulberry	10 thousand trees	960	1500	1701
Silkworm cocoon	ton	470	750	1000
Raw lacquer	ton	6.5	18.3	50
Out-shed pig	thousand	70	119	140
Out-shed sheep	thousand	20	55	77
Out-shed cattle	thousand	1.5	3.6	5.4

Table 11 shows the projected energy demand in different sub-sectors based on long-term development goals and the existing consumption pattern. The existing consumption pattern is shown in Table 12.

Table 11: Energy Demand Forecast in Ningnan County, 1990 to 2000

Energy Demand	Unit	1985	1990	2000
Industrial energy consumption	TOE	17262	40800	73400
Agricultural energy consumption	TOE	1900	2480	3200
Transportation energy consumption	TOE	535	900	1580
Daily life energy consumption	TOE	44558	36720	36350
Total energy consumption	TOE	64255	80900	114530

Based on the county's energy resources, energy demand projections, suitable energy technologies and energy conservation measures that can be realised economically, the structure of different types of energy consumption has been projected as shown in Table 13.

Energy Planning and Programme Implementation in Ningnan County

Energy planning in Ningnan County should aim at achieving the following objectives:

1. meet the energy demand of industrial, agricultural, and household sectors by developing medium and large-sized hydro-stations and biogas digestors in order to reduce the dependance on biomass energy,
2. achieve a higher level of efficiency in the use of firewood and other biomass energy by promoting improved stoves and other such technologies, and
3. promote new energy technologies such as solar energy, wind energy, etc in the processing of agricultural products.

Ningnan has abundant hydropower potential. The rural and urban electric power demand for industrial purposes and for lighting can be met by exploiting the hydropower potential of the county. At the end of 1986, the county had a total of 198 hydropower stations, with a total installed capacity of 4,966 kW, and an annual electricity generation of 9.32 million kWh. The county has a 161 km of 10 kV transmission line and a 930 km of low voltage distribution line, catering to 81 per cent of the rural households. However, to minimise investment and land inundation in the river valley areas, all the hydropower stations in Ningnan are 'run off the river' plants with no regulation reservoirs. The capacity of the station in the rainy season is much higher than in the dry winter season.

Table 12: The Domestic Energy Consumption of Some Rural Households in Ningnan County

Name of Person	No. of Pig	Number Raised	Fuel Consumption (kg)				Fuel Consumption in TOE Equivalent	Per Capita Fuel Consumption Per kg of Oil	Note
			Firewood	Stems	Grass	Others			
River Valley Areas:									
Zhou Kaiyin	4	5	1700	500	1500		1.21	301	
Zhou Kailiang	7	4	500	2500	1500		1.60	230	
Zhou Kaiqin	8	7	400	750	3500		1.65	206	With efficient stove With fuel efficient stove and biogas
Su Guizhi	7	6	400	200			0.23	33	
Partly Mountainous Areas:									
Li Huiguang	4	4	5300	700	2000		3.06	766	
Fu dayi	3	2	1800	300	1500		1.35	450	
Song Defen	7	4	3150	1350	1500	250	2.51	358	
Chen Xing	5	2	2715	1050	300	75	1.59	318	
Li Mingde	4	3	300	900	800		0.75	188	With biogas digester

In order to produce a steady power supply, the present power stations should be supplemented by coal-fired power plants or diesel generators. As per the projection of economy in the county, 10 thousand kW of additional installed capacity will be required to meet the power supply by 2000 A.D. The funds for hydropower development should mainly come from the banks. The small hydropower plants will be managed by the owner farmers themselves, whereas bigger plants will fall under the management of the Electric Power Company of the county.

Among the other energy technologies, biogas, wind power, and solar power are also suitable for the county to a certain extent. Solar energy in particular can be used for processing agricultural products. Because the equipment used in tobacco curing is very simple and crude the combustion efficiency is rather low. Hence, a large amount of firewood is wasted every year. The Government is presently developing new equipment which has high efficiency and can improve the quality of tobacco. The development of biogas digestors at the household level requires a certain level of household income and education. Hence, this technology should be promoted in the river valley areas and in the lower part of the middle mountain area where farmers are relatively better off. To combine biogas development and agricultural production, the comprehensive use cycle of energy-food-fertiliser should be tested by selected rural households on an experimental basis. If it proves successful, then it should be disseminated in a planned manner.

Table 13: Forecast of Energy Consumption Structure in Ningnan County, 1990 and 2000

Unit: TOE

Energy Sources	Energy Consumption in		
	1985	1990	2000
Commercial Energy:			
Coal	8253	16000	35000
Electricity	3807	9400	22000
Gasoline	1181	2500	5330
Kerosene	179	150	100
Diesel Oil	547	1000	2500
Coke	53	70	100
Total	14070	29120	65030
Non-commercial Energy:			
Firewood	20771	18000	16000
Crop stems	13604	12000	10000
Grasses	8828	9000	7500
Bagasse	673	12000	15000
Biogas	260	780	1300
Total	50236	51780	49800
Total Consumption	642552	80900	114830

To meet the firewood demand in the firewood deficient river valley area and the middle mountain area, plantation of fuelwood trees on the uncultivated land should be started.

On the other hand, technology for the efficient use of firewood should be promoted extensively. Skilled village workers, such as brick layers, should be trained and they should be provided with soft loans to begin enterprises for producing and marketing improved cooking-stoves.

Summary and Conclusions

Non-commercial energy sources, such as firewood, crop stems, grasses, and bagasse account for 78 per cent of the total energy consumption in Ningnan County. Commercial energy sources include coal, electric power, and fossil fuel. Except for electricity, the commercial energy consumed in the county is from external supplies. Although the hydropower potential of the county is considerable, uneven distribution of the runoff resulting from the uneven precipitation pattern makes the full use of this potential difficult.

The share of the household sector in the total energy consumption is roughly 69 per cent. This is because the industrial sector is not well developed and energy needs in the agricultural sector are met mostly by human and animal labour. Biomass energy constitutes nearly 96 per cent of the energy consumed in the household sector, with firewood alone contributing about 46 per cent.

Although the present level of household firewood consumption can be met by the existing forests, the exploitation of forest resources is not carried out being done in a rational manner. In addition, the present use of biomass energy is low in efficiency because of substantial wastage. There is, thus, a need to develop and popularise energy-saving techniques. In addition, the development and use of new energy sources, including biogas, solar power and wind power, should be promoted. In order to meet the increasing demand of industrial, agricultural, and household sectors and to reduce the dependance on biomass energy sources, medium and large-scale hydro stations should be developed. The funds for hydropower development should mainly come from banks. The small hydropower plants should be managed by owner farmers themselves, and the larger ones should fall under the management of the Electric Power Company.

ICIMOD is the first international centre in the field of mountain development. Founded out of widespread recognition of environmental degradation of mountain habitats and the increasing poverty of mountain communities, ICIMOD is concerned with the search for more effective development responses to promote the sustained well being of mountain people.

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ICIMOD serves as a multidisciplinary documentation centre on integrated mountain development; a focal point for the mobilisation, conduct, and coordination of applied and problem-solving research activities; a focal point for training on integrated mountain development, with special emphasis on the assessment of training needs and the development of relevant training materials based directly on field case studies; and a consultative centre providing expert services on mountain development and resource management.

Mountain Infrastructure and Technology constitutes one of the four thematic research and development programmes at ICIMOD. The programme aims at achieving environmentally sound infrastructural development practices as well as the use of innovative technologies for alleviating drudgery and improving the living conditions of mountain inhabitants. This is carried out through state-of-the-art reviews, field studies, pilot training, and applied research. Currently, the main focus of the programme is on mountain risk engineering with special reference to hill road construction, decentralised district energy planning and management, as well as appropriate mountain technologies.

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