Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
China’s rural electricity market—a quantitative analysis

Ming Yang\textsuperscript{a,*,1}, Xin Yu\textsuperscript{b,1}

\textsuperscript{a} International Consulting Group, Level 2, 120 Collins Street, Melbourne, Victoria 3000, Australia
\textsuperscript{b} Energy Economics and Technology, 12 Kiah Street, Glen Waverley, Victoria 3150, Australia

Received 27 September 2003

Abstract

The objective of this paper is to quantify the development of the rural electricity market at county level and below in China. A sectorial energy demand analysis and forecasting model was developed to analyze six Chinese provinces with different economic backgrounds. Historical data for over 20 years were collected on rural economic development, households, population, per capita income, community infrastructure development, capital investment, electricity consumption, output values in agriculture sector, and township and village enterprises (TVEs). This paper concludes that by 2010, annual electricity demand will increase at a rate between $-1.40\%$ and $15.60\%$ (depending on the sectors and provinces). It also recommends a preferred order for future rural electricity investment: Jiangsu, Hebei, Henan, Shaanxi, Liaoning and Xinjiang, i.e. from the most to the least developed provinces, if the investment objectives are to find the best market return and the greatest impact on rural market development.

© 2003 Elsevier Ltd. All rights reserved.

1. Introduction

Over the past few decades, China has successfully implemented economic system reforms in rural areas, and as a result, the rural electricity market is expanding quickly. From January 1998 to September 2003, the Chinese government invested 380 billion Yuan (US$46 billion) in urban and rural electricity market development [1]. Its goal was to stimulate domestic demand and push economic development in China, given that about 950 million people (75\% of the country’s population) are living in rural areas.

However, very little of China’s rural electricity market is known to the public due to a lack of research and a rapid development of the market. Many questions remain unclear, such as “what
are the shares of electricity consumption in rural areas?”, “how and where will these parameters change in rural China?”, “how much electricity will a rural household consume?”, “which part of China will incur the greatest rural electricity expansion by 2010?”, and “what is the priority order of investment in rural electricity markets? The objectives of this paper are to establish a model to identify and assess rural electricity market development in China as well as answer the above questions.

In this research, we collected a large amount of rural, social and economic data for six provinces in China. We grouped the provinces according to their economic and geographical conditions. Jiangsu and Liaoning were selected and grouped together because (1) they both have good economic development conditions in rural areas; and (2) they are both located in the eastern coastal area. Liaoning is in northeast and Jiangsu in east China. These two provinces represent China’s well-developed areas. Hebei and Henan, located in central China, are grouped together to represent China’s mid-developed provinces. Finally, Xinjiang and Shannxi, located in the western region of China, represent China’s least developed provinces. These three groups will also represent six electricity markets that the Chinese government plans to establish for power retail competition by 2005. We forecast electricity demand in the rural areas of the six provinces and tried to identify the best investment market in terms of high growth rate of electricity demand and greatest impact on rural electrification and economic development.

The paper is comprised of five parts. In Section 2, we present literature reviews on the electricity market. This includes brief assessments of China’s electric power sector and provides visions of the rural electricity market that leads to the focus of this study. Our model, methodology and approaches are discussed in Section 3. In Section 4, we analyze data, describe variables, and state scenarios used in the study. Section 5, the key section of this paper, presents our results. Section 6 shows the weaknesses and limitations of this research and directs further research in this topic. Conclusions and recommendations are presented in Section 7. Finally, we have included a summary of electricity market information for the six provinces in Appendix A. The information presented in this paper will be useful to policy makers in China and other developing countries when planning for rural electrification and electricity full retail competition.

2. Review of rural electricity market and power sector

2.1. International experience in rural electricity market development

Very few articles and documents are available in detailed quantitative analysis for the rural electricity market. Historical papers in this field mainly focus on electricity market reform, urban electricity market, and qualitative analysis. Yang [3] presents an international literature review on rural electricity market development with case studies for the USA, Thailand and Lao People’s Democratic Republic (Lao PDR). The paper summarizes the following:

(i) Investing in rural electricity market in general is not financially viable but economically sound and socially friendly. Private sectors have little incentive to participate in rural electricity market development. Instead, governments should initiate and/or invest in rural electricity development programs.
The main objectives of the government in rural electricity market development include poverty reduction, rural economic development, sustainable development in rural areas, and mitigating the migration from countryside to city.

2.2. Review of China’s power development

Yang and Yu [2] reviewed and examined the evolution of China’s power sector for the period 1949–1995. The paper covers the areas of institutional development and reform of China’s power industry, power shortages in the 1980s, power supply by different resources, capital investment structure, tariff policies, demand side management, energy efficiency policies and practices, laws in the power industry, and environmental impact from power generation.

Between 1995 and 2001, two additional hot topics have been added to China’s power literature: (1) continued reform of the power industry aiming at establishing a full retail market for power sector competition; and (2) rural electricity market development. Yang [3] reviewed the Chinese government strategies during 1993–2001 on power system reform towards a market based power system. The paper summarizes that China’s rural market has been initially formed and can provide 98% of the rural households with electricity by 2001.

In 2002, the national government (the State Council) issued a national policy document (Document No. 5, 2002) and outlined four key issues in China’s power reform [4]. Rural electricity market development is one of the key issues in China. The Chinese government also established “Four Principles of Facilitations” to the development of the rural market. These are (1) facilitating economic development and poverty reduction; (2) facilitating the merger of urban and rural power systems (any separation is not allowed); (3) facilitating power supply cost reduction and alleviating farmers’ financial burdens; and (4) facilitating further power system reform in China.

2.3. China’s current electric power situation

China’s current electricity situation can be described in three key statements: (1) short of power supply; (2) electricity tariff reforming; and (3) electricity market development. The State Electricity Regulatory Commission said that power supply and demand in 2002 was generally balanced. In 2003, the demand exceeded the supply and 18 provinces, autonomous regions and municipalities (including Shanxi, Jiangsu and Shanghai) faced severe power shortages last summer that affected local economic and social development, particularly rural households’ daily lives [5]. The Commission attributed the shortages mainly to (i) the lack of electricity market analysis, (ii) incorrect power demand forecasting, (iii) the slow investment in power supply, (iv) climate change (hot summer), and (v) higher production by enterprises after the severe acute respiratory syndrome (SARS) outbreak. China’s policy makers are pondering responsive market strategies, hoping to accelerate electricity facility construction and balance power supply and demand by “breaking monopoly and introducing competition” during the coming years.

Following the splitting up of the State Power Corporation at the end of 2002, China plans to create six regional competitive power markets within 3 years in a determined move to break up the traditional province-based electricity monopolies. These comprise: north, northeast, east, west, central and south electricity markets. When established, the markets will be able to sup-
port a power plant to sell electricity within the local market as well as export to other markets as long as the transmission line capacities are sufficient. Similarly, an end-user will be able to choose a power supplier either inside or outside of his own market system. This is called a “Full Retail Competition Market” in China. Evidently, rural electricity market development plays a very important role in China’s power reform.

2.4. Vision of China’s rural electricity market and main focus of this study

By the end of 2002, China still had about 20 million poor people, most of whom could not access electricity. According to the China Statistical Press [6], one rural family has 4.25 people. Thus, 20 million rural residents would be equivalent to about 4.7 million rural households. If US$3300 is required today to electrify one rural family [3], about US$14.6 billion is needed. Developing the rural electricity market, providing power for these people and raising them above the poverty line by 2010 (with limited funds) is a great challenge to the Chinese government and the power industry.

In the coming decade, China’s rural electrification has multiple tasks. The first task should be rural electricity demand forecasting and rural market development planning. The results will assist the government in arranging capital and formulating policies. The second task should be the implementation of institutional reforms to strengthen the rural electrification results. In the long run, the reforms will encourage full retail competition in the rural electricity market. The third task would be the continuation of the “Brightness Program” and the “Developing Rural Power with Wind Program”. These programs are very important to electrify remote households with renewable energy technologies, especially in the western region of China.

In this study, we focused on electricity market analysis and power demand forecasting for the rural areas—county level and below. A sectorial electricity demand model was developed. On the basis of available data, we divided the rural electricity market into several sectors: township and village enterprises (TVEs), agriculture and other family business, and households. Value added, energy intensity and market share of the economy are the main variables in the study. The model and variables are discussed in detail.

3. Methodology and models used in this study

The theoretical study of electricity market started in the middle of the 20th century with the development of computer science. However, progress in theory and practice was slow during the initial period. It was not until the 1980s that the theoretical study of medium-to-long-term electricity demand forecasting began. A series of forecasting methods, such as top–down econometric modeling and bottom–up end-use accounting modeling, was successively developed and widely accepted in the electricity demand forecasting of power systems [7]. Having reviewed the literature of energy modeling, Lin made an analysis of energy demand forecasting for China by using an econometric model. The article states that econometric models using GDP and electricity tariff as main driving variables may have at least one disadvantage. Since the economic variables employed in the econometric model are likely to be endogenous, estimating electricity demand by a single equation may produce simultaneous bias and lead to unreliable forecasts. There could be many other factors that require proper attention in determining electricity
demand in China’s rural area. An important one, for example, is the climate. Dry climate in a year means that more electricity is needed for irrigation. Cold or gloomy days mean that more electricity will be generally used for heating and lighting. Electricity demand also varies according to the time of day. Therefore, the demand for electricity in rural areas depends on climate changes and peak demands during cold and hot seasons. However, it is difficult to incorporate such climate change factors in an econometric model.

For our research, we used SEDA® V2, a well-developed mathematical computer model for sectorial energy demand analysis. We developed the first version to analyze the strategies of 10 Asian oil importing countries and economies during 1992–1996 [8]. In the current study, to describe energy consumption in rural households and capture the variable of “population”, we updated the model with a special module. In this section, we present part of the mathematical equations of SEDA® V2.

The total electricity demand (ED) in the rural electricity market is the sum of electricity demand for all sectors in a rural area. Mathematically, it can be expressed as follows:

\[ ED_t = \sum_{i=1}^{n} ED_{it} + ED_{Ht} \tag{1} \]

where \( ED_t \) is the total electricity demand, \( ED_{it} \) is the electricity demand in sectors not including rural households \( i (i = 1, 2, \ldots, n) \) in periods \( t (t = 1, 2, 3, \ldots, m) \), \( ED_{Ht} \) is the electricity demand in rural households in period \( t \).

Eq. (1) can be further formulated as follows:

\[ ED_t = \sum_{i=1}^{n} ED_{it} = \sum_{i=1}^{n} \frac{ED_{it}}{VA_{it}} \times \frac{VA_{it}}{GDP_t} \times GDP_t + \frac{ED_{Ht}}{NH_t} \times \frac{NH_t}{POP_t} \times POP_t \]

\[ = \sum_{i=1}^{n} EI_{it} \times S_{it} \times GDP_t + EI_{it} \times INH_t \times POP_t \tag{2} \]

where \( VA_{it} \) is the value added by sector \( i (i = 1, 2, \ldots, n) \) at period \( t (t = 1, 2, 3, \ldots, m) \) (billion 1999 Yuan); \( EI_{it} \) is the electricity intensity in sector \( i (i = 1, 2, \ldots, n) \) at period \( t (t = 1, 2, 3, \ldots, m) \) (GW h/million Yuan); \( S_{it} \) is the economic shares of the rural economy in sector \( i \) at period \( t \) (%); \( GDP_t \) is the gross domestic product of rural economy at period \( t \) (billion 1999 Yuan). Since rural GDP is not available, we use rural economic output in this study; \( NH_t \) is the number of households at period \( t (t = 1, 2, 3, \ldots, m) \); \( EI_{it} \) is the electricity intensity in rural household at period \( t \) (kWh/per household); \( INH_t \) is the inverse of the number of people per household at period \( t \) (household/number of people); \( POP_t \) is the rural population at period \( t \) (million persons).

By differentiating Eq. (2), we derived

\[ dEC_t = \sum_{i=1}^{n} [EI_{it} \times GDP_t \times dS_{it} + S_{it} \times GDP_t \times dEI_{it} + EI_{it} \times S_{it} \times dGDP_t] + EI_{it} \times INH_t \times dPOP_t + EI_{it} \times POP_t \times dINH_t + INH_t \times POP_t \times dEI_{it} \tag{3} \]

where \( dEC_t \) is the electricity demand change in period \( t \) in rural market, \( \sum_{i=1}^{n} [EI_{it} \times GDP_t \times dS_{it}] \) is the electricity demand change in rural market in period \( t \) due to structural effect, \( \sum_{i=1}^{n} [S_{it} \times GDP_t \times dEI_{it}] \) is the electricity demand change in rural market in period \( t \) due to sectoral effect,
\[
\sum_{t=1}^{n} [EI_{it} \times S_{it} \times dGDP_{t}] \]
is the electricity demand change in rural market in period \( t \) due to activity effect; \( EIH_{t} \times INH_{t} \times dPOP_{t} \) is the electricity demand change in rural households in period \( t \) due to population change in rural area; \( EIH_{t} \times POP_{t} \times dINH_{t} \) is the electricity demand change in rural households in period \( t \) due to the change of number of people per household; \( INH_{t} \times POP_{t} \times dEIH_{t} \) is the electricity demand change in rural households in period \( t \) due to the change of electricity intensity per household.

On the basis of historical data and scenarios, we used the above model to analyze the rural electricity market year by year from 2001 to 2010. In determining the changes of the parameters (\( dS_{it} \), \( dEI_{it} \), etc.), we analyzed the historical values of the variables and used scenario analysis on the basis of China’s 10th Five-Year Economic and Social Development Plan, and interviewed with Chinese government officers on social and economic development policies. In the next section, we will discuss the data, variables, and their processes for fitting the model.

4. Variables and scenario descriptions

A panel dataset including six provinces over the period from 1978 to 2000 was constructed from various governmental sources [9–15] and on-site interviews with many experts in China. In addition, we projected data for the period 2001–2010 for electricity market analysis. In the following example, we briefly describe the methods used in preparing several historical data in the research.

4.1. Data of rural households, irrigation, agriculture, industry and TVEs

The rural economy was divided into five sectors: TVEs, agriculture, county level industry (industry), household, and others. Given that we only had output data for the county industrial sector in 2000, we estimated industrial outputs below county level and presented the results between 1978 and 1999 by using provincial GDP for the period. Since we did not have any output data for other sectors, we simply assumed growth rates and projected the electricity increase in the period 2000–2010. In the following, we first analyze historical electricity market.

Electricity consumption by rural households, rural irrigation, agriculture, and TVEs in each of the six provinces for the period 1978–2000 is collected to analyze the rural electricity market.

4.2. Main variables used in electricity market analysis

On the basis of the research objectives and the available data, we used the primary variables defined in Table A.1 for this study.

4.3. Data collection

We collected data of 2001–2005 from the Chinese government [16]. The following list presents the main collected data.

(i) Yearly national economic growth rate: 7%. This scenario will guide the assumptions of TVE output and other sectors’ output in the six provinces.

(ii) Creating new jobs and transferring rural residents to urban residential areas in 5 years: 40 million. This information tells that rural population might keep decreasing or stable in the future years due to migration.
(iii) Shares of primary, secondary and service industries in 2005: 13.00%; 51.00% and 36.00%  
(the past trend in year 2000: 15.90%, 50.90%, and 33.20%). These shares guide the structure changes in the rural economy from 2000 to 2005.

(iv) Shares of employees in the primary, secondary and service industries in 2005: 44.00%; 23.00% and 33.00% (the past trend in 2000: 48.70%, 23.00%, and 28.30%). The change of these shares between 2000 and 2005 will also guide the structure of rural economy.

(v) Yearly population growth rate: 0.90% (The historical trend in 1998: 0.93%). These data help determine population growth rates for each of the six provinces.

(vi) Net income of rural residents growth rate: 5.00%. These data are used to set household income in future years.

During a field trip to China, the prime author interviewed a number of Chinese experts and government officers regarding economic and social development trends for the selected six provinces\(^2\). The following information was collected from the trip:

(i) Electricity intensity for rural irrigation will increase slightly after rural electrification. Lower electricity prices reduce labors and increase machines in agriculture production.

(ii) Electricity intensity for TVEs industry will continue to decrease because TVEs will change their structure from high electricity intensity industries to low electricity intensity industries.

(iii) Electricity intensity for “other sectors” will decrease slightly because of the electricity conservation effect and increasing outputs from newly developed low electricity intensive enterprises.

(iv) Economic development will grow at similar speed of 1999–2000 at the beginning of 2001–2010 but this speed would become slower at the second half of the 10 years.

(v) The number of people in a rural household will slightly decrease at the trend during 1995–2000 due to the government policy of birth control, economic development in rural areas, urbanization and migration. Annual rural population growth rate will remain low.

(vi) Net rural per capita income growth rates in real prices: Jiangsu: 7–8%; Liaoning: 5%; Henan and Hebei: 4%; Shaanxi: 6–7%; Xinjiang: 4–5%\(^3\).

(vii) Inflation rate may keep between 2% and 5%.

(viii) The growth rates of TVEs will be the same as those of individual provincial industries.

(ix) The Chinese government will continue to invest in rural electrification. During 2002–2004, the government will invest an additional 100 billion Yuan.

(x) The government’s rural network investment during 1998–2000 (189 billion Yuan) did not have significant impact on electricity consumption of rural agriculture production because the objective was to retrofit the power network for household electricity supply only. However, reduced tariffs will in some way stimulate electricity consumption in agriculture production.

\(^2\) See the name list in the section of acknowledgements of this article.

\(^3\) Jiangsu: strong economic base; Liaoning: strong economic base but not as strong as Jiangsu; Henan and Hebei in Central China, China’s West development favorite economic development polices do not apply; Shaanxi strong economic base and China’s West development polices applicable. Xinjiang: weak economic base.
Electricity intensity in TEV and other sectors might decrease due to electricity conservation and business structure change. However, it will be at a slower rate than during 1995–2000 because electricity conservation will be more expensive.

Rural market reform will continue to aim at full retail competition.

In rural electricity market development analysis, we divided the future 10 years into three time sections: 2001–2002, 2003–2005 and 2006–2010. In the first section, we mainly considered the historical data of 1995–2000 to set growth rates. In the second and third sections, we took into account both historical trend, future scenarios and findings.

5. Electricity market analysis

In order to keep the article within a reasonable length, we have described the case of Jiangsu in detail and combined the discussion and results of the other provinces.

5.1. Historical electricity market analysis for Jiangsu

Table A.3 in Appendix A shows the results. The following historical facts can be observed in the table:

(i) Electricity consumption in other sectors (including postal, telecommunication, and other services) had the highest annual average growth rate reaching about 28.50% per year over the past two decades, increasing more than 248 times from 14.5 GW h in 1978 to 3609 GW h in 2000. However, since it was a newly developed sector, its share in the total electricity consumption was relatively small, less than 7% in 2000.

(ii) The household sector had the second highest average growth rate (17.60%) and a significant market share (17.70%) in 2000. The total households consumed 9081 GW h of electricity in that year.

(iii) County level industry was the largest electricity consumer in 1978 with a share of 61.00%. Due to a structural change, its share has decreased over the past two decades. By 2000, this figure was 37.60%. However, the electricity consumption was increasing at an average rate of 7.60%.

(iv) TVEs increased electricity consumption both in quantity and in share. Electricity use increased from 606 GW h in 1978 to 15,381 GW h in 2000, with an annual growth rate of 15.80%.

(v) Electricity consumed by agriculture had the least annual growth rate (5.20% only); hence its share decreased from 25.50% in 1978 to 9.50% in 2000. This might have been caused by good climate conditions for farming, urbanization and industrialization in rural areas.

(vi) Total electricity consumption in Jiangsu increased 7.1 times from about 6545 GW h in 1978 to 53,120 GW h in 2000, with an annual average growth rate of 10.00%.

5.2. Electricity future market analysis for Jiangsu

Table A.3 in Appendix A also presents the projected results of the future electricity market by sector in Jiangsu:
(i) Electricity markets in all sectors will continue to grow; however, growth rates will decrease over the years.

(ii) Between 2001 and 2010, the electricity market shares in agriculture and TVEs may decrease and those of household, county industry and other sectors will increase.

(iii) By 2005 and 2010, electricity demand will be 5273 and 5822 GW h for agriculture; 14,871 and 15,537 GW h for TVEs; 30,135 and 42,463 GW h for county industry; 13,591 and 19,063 GW h for households; and 5256 and 8087 GW h for other sectors, respectively.

(iv) The total electricity demand in the Jiangsu rural market will increase from 53,119 GW h in 2000 (at an average rate of 7.80%) to 69,128 in 2005 and to 90,947 GW h in 2010 (at an average growth rate of 5.53%).

5.3. Electricity market analysis for Liaoning, Hebei, Henan, Shaanxi and Xinjiang

In addition to Jiangsu, we have quantitatively analyzed electricity markets for Liaoning, Hebei, Henan, Shaanxi and Xinjiang. The analysis for the five provinces followed the same procedure as that of Jiangsu. Tables A.3–A.8 presents the main results of the electricity market analysis and are summarized as follows:

(i) The electricity market shares in Liaoning are as follows: agriculture increasing from 9.00% in 2000 to 10.70% in 2005 and 12.50% in 2010, and all other sectors decreasing slightly over the next 5–10 years. The agriculture and county industry sectors will be the largest electricity consumers in the coming 5–10 years with total electricity consumption of 3604 and 10,214 GW h in 2010, respectively. The household sector maintained almost the same growth rate for the period 1995–2000, at about 3% in 2001–2005. This rate would drive electricity demand by household up to 5996 GW h in 2005. Electricity consumption by other sectors, increasing at the rate of about 3% between 2001 and 2005, would be 1781 GW h in 2005. When the above elements are taken into consideration, electricity demand in Liaoning will increase from 20,184 GW h in 2000 to 23,942 GW h in 2005 and to 28,785 GW h in 2010.

(ii) In Hebei, the research results show that the market shares of agricultural and households would augment over the next 5–10 years. Electricity demand in these two sectors would be 11,464 GW h for agriculture, 11,322 GW h for household in 2005, 17,113 GW h for agriculture and 16,752 GW h for household in 2010, respectively. TVE might need moderate electricity growth over the next 5 years and the quantity would be 9153 GW h in 2005. The county industry sector is projected to increase electricity demand by 7.10% each year over the next few years. This would double electricity consumption from 1995 to 2005. Electricity demand in other sectors may continue to increase slowly due to a decrease in intensity and market share. The total electricity consumption could grow at a rate of 8.34% per year from 2000 to 2005, reaching 49,644 GW h in 2005.

(iii) Electricity consumption in Henan for the period 2001–2005 would almost keep the same growth rates as in the period 1995–2000. County industry is the largest electricity consumer with 17,553 GW h in 2005, although its market share may decrease from 46.60% in 2000 to 44.30% in 2005. Household and other sectors will have the highest annual growth
rates and both will increase their shares in the coming 5–10 years. Electricity consumption in Henan rural areas will total 39,658 GW h in 2005 and 50,162 GW h in 2010, increasing by about 4.81% each year.

(iv) The electricity market shares in Shaanxi during 2000–2010 will be as follows: stable in TVEs and other sectors, decreasing in agriculture, but increasing in household. Electricity consumption in 2005 may be 2075 GW h for agriculture with annual growth rate of 0.8%, 4022 GW h for TVEs with the rate of 10.30%, 3982 GW h for county industry with 7.60%, 3837 GW h for household with 10.20%, and 1940 GW h for other sectors with a yearly growth rate of 11.60%. The total electricity demand will amount to 15,856 GW h in 2005 and 22,014 GW h in 2010 in Shaanxi rural areas.

(v) In Xinjiang, the electricity growth rates in all sectors increased at high rates during 1995–2000. This high consumption trend might continue in the next 2 years and with a moderate growth rate in the years to follow. According to our analysis, county industry in Xinjiang will be the main marginal consumer of electricity with share growth increasing from 22.90% in 1995 to 45.00% in 2005. Electricity consumption by other sectors will continue to decrease between 1995 and 2005. The household sector share will decrease from 15.10% in 2000 to 13.30% in 2005. The total volume of the electricity market will increase from 6222 GW h in 2000 to 9318 GW h in 2005 at an annual rate of 8.41% ranking the highest in growth rate of all the provinces. In 2010, 12,571 GW h of electricity will be required for all of the sectors.

5.4. Comparative analysis of electricity market development for six provinces

Electricity market development, ranked according to size, is as follows: Jiangsu, Hebei, Henan, Liaoning, Shaanxi and Xinjiang. Electricity demand in 2005 in Jiangsu would amount to 69,128 GW h while this figure in Xinjiang would be only 9318 GW h. All provinces will experience growing electricity demand during all periods with the exception of Liaoning in the period 1995–2000. This may be a reflection of statistical and data collection during the 1990s, Liaoning changed its rural statistical and data processing methodologies. The province treated many rural people in counties and towns as urban population. As a result, rural population and electricity consumption statistically decreased quickly during that period.

Table A.2 and Fig. 3 comparatively highlight the analysis results of electricity markets for the six provinces. It is observed that Jiangsu, Hebei and Henan have good rural electricity development potential with both high volumes of electricity demand bases and fast growing rates in the coming 5–10 years.

---

4 SP expert (WSX) projected that electricity demand in Xinjiang in 2000–2010 would not be very high.

5 During the 1990s, Liaoning changed its rural statistical and data processing methodologies. The province treated many rural people in counties and towns as urban population. As a result, rural population and electricity consumption statistically decreased quickly during that period.
6. Further discussion of the model and the study

Among the strengths of the model and the study include conciseness, flexibility, and understandability. The model is developed on the basis of basic theory of energy economics. The study approach can be operated by a professional if he has experience in running computer models and undertaking such energy market analysis assignments.

Since SEDA® is a bottom–up accounting model, there are a couple of weaknesses or limitations in the research. A bottom–up accounting model requires a large amount of data. If more detailed data is available, the energy sector can be further broken down, and more accurate model results can be achieved. However, data shortage is one of the main limitations in China. Household business income and county industry output, for example, are not statistically avail-
able. We had to estimate the data. In addition, due to the reform of the statistical system and a change in methodology, some historical data are not consistent throughout the history. For example, the statistical methodology for rural population and economic sectors in Liaoning has been changed in the early 1990s. Many people living in rural areas have been statistically treated as urban residents. As a result, the rural population according to the Chinese official statistical data has been decreasing very quickly. By 1999, there were about 4.3 million people in Liaoning’s rural areas. This figure may not be true. As another example, energy consumption by county small industries has been statistically presented in the industry sector. In recent years, the State Power Corporation has treated electricity consumption at county level and below as rural electricity consumption.

A further limitation of the bottom–up accounting model is that it does not explicitly apply the variables of energy price and income. However, these variables have been acknowledged implicitly in the model. For example, a survey on willingness to pay for electricity at different prices and different income levels has been undertaken in the research and the information has been incorporated in setting the growth rate of household energy consumption.

The model can be used to undertake detailed cross-sectorial analysis of similarities and differences among provinces. Part of the mathematical formulas of the model for such analysis was stated in Yang [8]. However, conducting such analysis might become the scope of another paper.

Nevertheless, the main significance of this study is that we used a computer-supported model to analyze the electricity market and forecast electricity demand for the Chinese rural areas. The availability of this type of analysis is scarce in the history and literature.

---

6 The impact of China’s rural economic reform on rural sectoral energy consumption—an article in preparation.
7. Conclusions and recommendations

There is a great electricity market development potential in China’s rural areas. Even if the Chinese rural residents are far above the poverty benchmark, their electricity consumption is very low. For example, in Jiangsu—the most developed province among the six ones, the average per capita income of a rural resident was more than 4300 Yuan/year/capita (US$530) in 2000. If there are four people in a rural family in Jiangsu, the family income will be 17,000 Yuan/year (US$2100/year). With this income, the family can purchase all the basic family electric appliances such as a TV, a refrigerator, a washing machine in 1 or 2 years. However, our findings show that electricity consumption per family in Jiangsu rural area was about 1.3 kWh per day. This amount of electricity can only run a refrigerator. It is evident that electricity demand by rural households will be very high. After retrofitting the rural power network (rural electrification) and cutting down the rural electricity prices, electricity consumption in rural households will increase quickly.

In the agriculture sector, electricity consumption will also increase during 2000–2005, even though the sector has declined in electricity consumption in some provinces. After the mass investment in the rural power network since 1998 and rural institutional reform, electricity tariffs in China’s rural areas have been reduced and this has facilitated electricity substitution for labor and diesel in agriculture production.

TVEs and county industry have been increasing consumers in the rural electricity market. Given that TVEs and county industry will be the most important economic sectors in the rural economy between 2000 and 2010, electricity demand will continue to grow. The average annual growth rates of TVEs between 2000 and 2005 in the six provinces are in the range from 2.87% in Liaoning to 12.60% in Xinjiang, while the rates for county industry are between 3.00% in Liaoning and 0.90% in Jiangsu.

Electricity demand for other sectors will continue to grow but the shares are not significant in the near future. The reason is that the service industry in rural areas has not been developed well and the shares of electricity demand in total are small, ranging from 3.90% in Henan in 2005 to 13.90% in Xinjiang in 2005 (see Table 1).

On the basis of the above electricity market analyses, we would recommend the preferred future rural electricity market investment in the following order: Jiangsu, Hebei, Henan, Shaanxi, Liaoning and Xinjiang. This implies the following order of investment for the development of six national electricity markets: East and South China electricity markets, North and Northeast China electricity markets, and Central and Western electricity markets.

Acknowledgements

Acknowledgements are due to the anonymous referees for their excellent comments on the previous versions of the article. The authors are indebted to the editor-in-chief of Energy—The International Journal for his constant encouragement and advice on refining this article. The

Source: Author’s personal contact with the Department of Rural Electrification of the State Power Cooperation in Beijing in 2001.
authors express their many thanks to Ms Valerie Mosley and Mr Chunhua Li of the International Consulting Group for their comments and proof-reading of the paper. Finally, the authors wish to thank Mr Wang Shu Xiang, Mr Hu Zheng Hua, Mr Zhang Yang Ming of Rural Electrification Department, State Power of China; Yi Xiao Lin, China’s Rural Academic Research Institute; Prof. Yao Yu Fang of Chinese Academy of Social Science; Mr Li Wen Zheng and Dr Bai Jian Hua of the Beijing Economic Research Institute of Water Resources and Electric Power, and Mr Han Wen Ke of Energy Research Institute of the State Development Planning Commission of China for data collection. The viewpoints expressed in this article are solely those of the authors and do not represent those of the persons mentioned above.

Appendix A. Summary of electricity market information

Table A.1–A.3.

Table A.1
Variables and definitions

| Variables   | Units                        | Definitions                                                                 |
|-------------|------------------------------|-----------------------------------------------------------------------------|
| GDP         | Billion Yuan in 1999 constant price | Provincial gross domestic products                                           |
| INC-CAP     | Yuan in 1999 constant price  | Per capita income in rural areas                                            |
| AG-OUT      | Billion Yuan in 1999 constant price | Agricultural production output which includes outputs from farming, forestry, fishing and husbandry |
| INV-ELE     | Billion Yuan in 1999 price    | Capital investment in rural power network                                    |
| TVE-OUT     | Billion Yuan in 1999 constant price | Output of TVEs                                                                |
| IND-OUT     | Billion Yuan in 1999 constant price | Industrial production output, which only includes the outputs from county level industries |
| ELE-AG      | GW h                         | Electricity consumption by agriculture production                           |
| ELE-TVE     | GW h                         | Electricity consumption by TVEs                                              |
| ELE-INDUS   | GW h                         | Electricity consumption by county level industries                           |
| ELE-OTH     | GW h                         | Electricity consumption by all other sectors                                 |
| ELE-TOT     | GW h                         | Total electricity consumption in rural areas                                 |
| ELE-INV     | Million Yuan in 1999 constant price | Accumulated investment in the rural power network                          |
| NUM-HHS     | Million                      | Number of households                                                          |

Note: (1) Rural areas mean county city areas and areas below county cities.
Table A.2
Highlights of historical electricity consumption and future demand projection for the six provincial rural areas

|        | Jiangsu | Liaoning | Hebei | Henan | Shaanxi | Xinjiang |
|--------|---------|----------|-------|-------|---------|----------|
|        | Demand (GW h) | Growth rate (%) | Demand (GW h) | Growth rate (%) | Demand (GW h) | Growth rate (%) | Demand (GW h) | Growth rate (%) | Demand (GW h) | Growth rate (%) | Demand (GW h) | Growth rate (%) |
| 2010   | 90,973.9 | 5.79     | 28,785.2 | 3.78   | 68,529.6 | 6.76      | 50,161.8 | 4.93   | 22,014.6 | 6.86       | 12,570.8 | 6.30       |
| 2009   | 85,994.3 | 5.72     | 27,735.7 | 3.77   | 64,189.3 | 6.71      | 47,803.8 | 4.87   | 20,602.0 | 6.82       | 11,825.8 | 6.23       |
| 2008   | 81,341.5 | 5.65     | 26,728.6 | 3.75   | 60,151.7 | 6.66      | 45,583.7 | 4.81   | 19,286.4 | 6.78       | 11,131.9 | 6.17       |
| 2007   | 76,993.1 | 5.57     | 25,761.9 | 3.74   | 56,394.8 | 6.61      | 43,491.7 | 4.75   | 18,061.1 | 6.75       | 10,485.1 | 6.11       |
| 2006   | 72,928.4 | 5.50     | 24,833.8 | 3.72   | 52,898.5 | 6.56      | 41,519.3 | 4.69   | 16,919.6 | 6.71       | 9,881.7  | 6.04       |
| 2005   | 69,128.0 | 5.94     | 23,942.5 | 3.78   | 49,644.2 | 6.85      | 39,658.2 | 4.86   | 15,856.1 | 8.41       | 9,318.5  | 7.09       |
| 2004   | 65,252.3 | 5.84     | 23,070.1 | 3.76   | 46,463.1 | 6.78      | 37,820.6 | 4.78   | 14,625.8 | 8.30       | 8,701.8  | 7.01       |
| 2003   | 61,652.4 | 5.74     | 22,233.2 | 3.75   | 43,512.3 | 6.72      | 36,095.4 | 4.70   | 13,504.5 | 8.19       | 8,132.1 | 6.92       |
| 2002   | 58,307.8 | 4.92     | 21,430.3 | 3.04   | 40,774.0 | 7.97      | 34,474.2 | 4.94   | 12,482.3 | 8.27       | 7,605.5 | 10.79      |
| 2001   | 55,574.9 | 4.62     | 20,797.0 | 3.03   | 37,765.3 | 7.90      | 32,851.8 | 4.83   | 11,528.6 | 7.99       | 6,864.8 | 10.32      |
| 2000   | 53,119.4 | 14.89    | 20,184.8 | 11.02  | 34,999.5 | 8.32      | 31,377.5 | 4.34   | 10,675.3 | 16.71      | 6,222.4 | 14.84      |
| 1999   | 46,234.3 | 6.75     | 18,181.3 | 5.23   | 32,311.3 | 12.50     | 30,033.0 | 3.37   | 9,146.7  | 4.59       | 5,418.4 | 22.89      |
| 1998   | 43,309.7 | 1.98     | 17,277.4 | -4.38  | 28,721.9 | 4.14      | 29,052.5 | -1.19  | 8,745.4  | -1.55      | 4,409.3 | 31.90      |
| 1997   | 42,470.0 | 9.31     | 18,068.0 | 4.79   | 27,580.0 | 10.25     | 29,401.0 | 10.53  | 8,883.0  | 5.56       | 3,343.0 | 16.77      |
| 1996   | 40,327.0 | 3.38     | 17,242.0 | 7.09   | 25,016.0 | 10.20     | 26,599.0 | 9.96   | 8,415.0  | 7.75       | 2,863.0 | 4.11       |
| 1995   | 39,010.0 | 11.71    | 16,100.0 | 13.22  | 22,700.0 | 13.96     | 24,190.0 | 19.34  | 7,810.0  | 5.26       | 2,750.0 | 11.79      |
### Table A.3
Historical electricity consumption and future electricity demand by sectors

|                | Agricultural production | TVEs | County industry | Households | Other sectors | Total |
|----------------|-------------------------|------|-----------------|------------|---------------|-------|
|                | Electricity consumption (GW h) | Growth rate (%) | Share (%) | Electricity use (GW h) | Growth rate (%) | Share (%) | Electricity use (GW h) | Growth rate (%) | Share (%) | Electricity use (GW h) | Growth rate (%) | Share (%) | Electricity use (GW h) | Growth rate (%) | Share (%) |
| **Jiangsu**    |                          |       |                 |            |               |       |                          |            |           |                          |            |           |                          |            |           |
| 2010           | 5822.8                   | 2.0   | 6.4             | 15,537.6   | 0.9           | 17.1  | 42,463                     | 7.1        | 46.7       | 19,062.8                     | 7.0        | 21.0       | 8087.1                     | 9.0        | 8.9       |
| 2005           | 5273.9                   | 1.5   | 7.6             | 14,871.7   | 0.9           | 21.5  | 30,135                     | 8.1        | 43.6       | 13,591.5                     | 8.0        | 19.7       | 5256.1                     | 8.0        | 7.6       |
| 2000           | 5053.7                   | −17.0 | 9.5             | 15,381.0   | 28.5          | 29.0  | 19,994                     | 15.1       | 37.6       | 9081.2                      | 17.7       | 17.1       | 3609.3                     | 16.9       | 6.8       |
| **Liaoning**   |                          |       |                 |            |               |       |                          |            |           |                          |            |           |                          |            |           |
| 2010           | 3604.5                   | 7.1   | 12.5            | 5949.9     | 3.0           | 20.7  | 10,214                     | 3.8        | 35.5       | 6951.4                      | 3.0        | 24.1       | 2065.1                     | 3.0        | 7.2       |
| 2005           | 2555.6                   | 7.6   | 10.7            | 5142.4     | 2.9           | 21.5  | 8467                      | 3.9        | 35.4       | 5969.3                      | 3.0        | 25.0       | 1781.4                     | 3.0        | 7.4       |
| 2000           | 1821.7                   | −15.7 | 9.0             | 4464.4     | 20.9          | 22.1  | 7116                      | 16.9       | 35.3       | 5182.7                      | 7.8        | 25.7       | 1600.2                     | 11.7       | 7.9       |
| **Hebei**      |                          |       |                 |            |               |       |                          |            |           |                          |            |           |                          |            |           |
| 2010           | 17,113.5                 | 8.3   | 25.0            | 9987.4     | 1.8           | 14.6  | 22,211                     | 7.1        | 32.4       | 16,752.4                     | 8.2        | 24.4       | 2465.1                     | 4.9        | 3.6       |
| 2005           | 11,464.2                 | 7.6   | 23.1            | 9153.1     | 2.6           | 18.4  | 15,762                     | 7.1        | 31.8       | 11,321.9                     | 10.2       | 22.8       | 1942.6                     | 2.6        | 3.9       |
| 2000           | 8180.2                   | 2.3   | 23.4            | 7012.7     | 12.7          | 20.0  | 11,192                     | 12.5       | 32.0       | 6828.3                      | 6.7        | 19.5       | 1786.0                     | 2.3        | 5.1       |
| **Henan**      |                          |       |                 |            |               |       |                          |            |           |                          |            |           |                          |            |           |
| 2010           | 5678.5                   | 2.0   | 11.3            | 9113.3     | 4.0           | 18.2  | 20,863                     | 3.5        | 41.6       | 11,717.2                     | 9.3        | 23.4       | 2790.0                     | 7.5        | 5.6       |
| 2005           | 5140.7                   | 1.4   | 13.0            | 7508.5     | 4.1           | 18.9  | 17,553                     | 3.6        | 44.3       | 7512.4                      | 10.5       | 18.9       | 1943.4                     | 8.0        | 4.9       |
| 2000           | 4890.9                   | −17.5 | 15.6            | 6087.0     | 1.3           | 19.4  | 14,601                     | 14.8       | 46.6       | 4451.5                      | 4.5        | 14.2       | 1306.7                     | 17.2       | 4.2       |
| **Shaanxi**    |                          |       |                 |            |               |       |                          |            |           |                          |            |           |                          |            |           |
| 2010           | 2279.8                   | 1.9   | 10.4            | 5855.4     | 7.8           | 26.6  | 5341                      | 6.1        | 24.3       | 5676.7                      | 8.2        | 25.8       | 2861.6                     | 8.1        | 13.0      |
| 2005           | 2075.2                   | 0.8   | 13.1            | 4022.2     | 10.3          | 25.4  | 3982                      | 7.6        | 25.1       | 3836.6                      | 10.2       | 24.2       | 1940.4                     | 11.6       | 12.2      |
| 2000           | 2078.9                   | 7.2   | 19.5            | 2351.9     | 37.8          | 22.0  | 2928                      | 8.2        | 27.4       | 2235.0                      | 10.4       | 20.9       | 1081.7                     | 40.4       | 10.1      |
| **Xinjiang**   |                          |       |                 |            |               |       |                          |            |           |                          |            |           |                          |            |           |
| 2010           | 2731.1                   | 7.5   | 21.7            | 1269.6     | 13.0          | 10.1  | 5633                      | 6.1        | 44.8       | 1432.0                      | 3.0        | 11.4       | 1505.1                     | 3.0        | 12.0      |
| 2005           | 1902.4                   | 6.5   | 20.4            | 689.1      | 12.4          | 7.4   | 4193                      | 9.1        | 45.0       | 1235.2                      | 3.0        | 13.3       | 1298.3                     | 3.0        | 13.9      |
| 2000           | 1458.9                   | 1.0   | 23.4            | 380.6      | 7.0           | 6.1   | 2733                      | 31.4       | 43.9       | 937.3                       | 11.1       | 15.1       | 712.8                      | 2.6        | 11.5      |

Historical data from 1978 to 2000 are available by contacting the authors.
References

[1] BHI. China’s potential of power blackouts. Investment and Construction News. Beijing 2003;28 September [in Chinese].
[2] Yang M, Yu X. China’s power management. Energy Policy 1996;24(8):735–57.
[3] Yang M. China’s rural electrification and poverty reduction. Energy Policy 2003;31(2):283–95.
[4] Shao BR. The reform is not just for reform. China Power News. Beijing 2003;27 August [in Chinese].
[5] Xinhua News Agency. China faces power shortage. China Daily. Beijing 2003;5 October [in Chinese].
[6] China Statistical Press. China statistical year book 2000. Beijing: China Statistical Publishing House; 2001 [in Chinese].
[7] Lin BQ. Structural change, efficiency improvement versus energy demand forecasting—case study of China’s power sector. Economic Research Journal. Beijing: China 2003(5):57–65.
[8] Yang M. Strategies of Asian oil importing countries. Energy Sources 1997;19(3):205–17.
[9] China Statistical Press. Statistical yearbook of Jiangsu 2000. Beijing: China Statistical Publishing House; 2001 [in Chinese].
[10] Chinese Statistical Press. Statistical yearbook of Liaoning 2000. Beijing: China Statistical Publishing House; 2001 [in Chinese].
[11] Chinese Statistical Press. Statistical and economic yearbook of Henan 2000. Beijing: China Statistical Publishing House; 2001 [in Chinese].
[12] Chinese Statistical Press. Statistical yearbook of Hebei 2000. Beijing: China Statistical Publishing House; 2001 [in Chinese].
[13] Chinese Statistical Press. Statistical yearbook of Shaanxi 2000. Beijing: China Statistical Publishing House; 2001 [in Chinese].
[14] Chinese Statistical Press. Statistical yearbook of Xinjiang 2000. Beijing: China Statistical Publishing House; 2001 [in Chinese].
[15] State Power Cooperation—SPC. China rural electrification integration statistical book 2000. Beijing: Sate Power Cooperation; 2001 [in Chinese].
[16] China People’s Congress. The planning outline of China’s 10th five-year national economic and social development. A government policy paper approved by the Fourth Meeting of the Ninth People’s Congress of China, Beijing March 15. 2001 [in Chinese].