ELSEVIER

Energy Policy 28 (2000) 231–241

ENERGY POLICY

www.elsevier.com/locate/enpol

Long-term electricity demand in China — From quantitative to qualitative growth?

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Received 12 November 1999

Abstract

This paper develops scenarios of electricity demand in China until 2010, at a national, a sectoral and a regional level. It takes into account the recent macroeconomic downturn in the Chinese economy and the potential effects of deregulation and price increases in the power sector. The medium-growth scenario hints at a gross electricity demand of 1500 TWh in 2010; should the structural change from agriculture and heavy industry towards light industry and services accelerate, electricity demand may be another 10% lower. These figures are significantly below the projections fixed in the government's 9th five-year plan, which forecasts a demand of 2500 TWh. The aggregate and sectoral scenarios imply that current development plans for generating capacity and coal consumption until 2010, too, need to be scaled down. The disaggregation at the level of the 13 inter-provincial and provincial power grids hints at potential regional discrepancies: the large industrial areas in eastern China and the Central region are likely to face overcapacity, whereas North China and the peripheral regions may face deficits. © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: China; Electricity; Demand forecast

1. Introduction

China nowadays consumes over 10% of worldwide primary energy, whereas its share in global GNP is only 3.5%. Contrary to development countries, both the energy and the electricity intensity of GDP have been below unity over the last decade, resulting from a determined policy of energy conservation (Sinton *et al*., 1998). However, market forces, competition and full-cost pricing are still largely contained in the Chinese energy sector; environmental costs are not fully taken into account (Gan, 1998). With the decisions of the Chinese government to forster market-economic reform, the energy sector, too, is facing a new era, where quantitative indicators of growth may be replaced by market economy criteria. The 10th five-year plan, which is to be negotiated in 2000 and implemented in 2001–2005, may already incorporate such new orientations. In particular, the *electricity sector* may undergo fundamental changes from a system of local, state-owned monopolies to open competition, and eventually even privatisation.

Energy demand forecasts have traditionally played a key role in the Chinese development planning process. The government uses aggregate approaches to determine future energy consumption; thus far, bottom-up approaches are not practised. By contrast, the literature on the energy sector has developed more sophisticated models, such as adjusted input–output analysis (Garbaccio *et al*., 1999), and cointegration and vector error-correction models (Chan and Lee, 1996). However, all authors agree that the significance of the results is significantly reduced by data problems. For example, no serious, model-based demand forecast exists for the electricity sector.

In this paper, we adopt a pragmatic approach to forecasting electricity production and consumption patterns in China in the next decade, at the national, sectoral and regional levels. We challenge the official forecasts by integrating the perspective of regulatory changes in the sector. Indeed if electricity is to become a "market good", then demand may not increase as drastically as official forecasts are predicting; thus, the required increase in generation capacity, too, may be lower than expected. The paper is structured in the following way: the next

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0301-4215/00/$ - see front matter
PII: S0301-4215(00)00014-8

section provides a brief introduction to recent developments of the Chinese electricity sector. Subsequently, we develop electricity demand scenarios until the year 2010, applying different assumptions to a Cobb–Douglas function, which is considered to reflect the nature of demand developments properly. The aggregate scenarios are differentiated by income and price developments (that is high, medium and low growth). Then, two desegregated scenarios are outlined: the sectoral scenario captures different possible development paths of the Chinese economy, that is fast structural change against slow structural change. The regional scenarios analyse future generation capacities and consumption at the level of the seven inter-provincial and six provincial power networks. The last section discusses some policy implications.

2. The Chinese electricity sector on the eve of the 10th five-year plan

The Chinese electricity sector grew at two-digit rates in the early 1990s, but since the mid-1990s it has gone off the growth track prescribed by the 9th five-year plan (1996–2000). *Generation* capacity is expanding steadily, but its development is not as fast as forecasted five years ago. The installed capacity of about 270 GW (1999) is significantly below the 300 GW planning figure (1990 : 138 GW 1995, : 217 GW). On the *consumption* side, the deviation is still more evident: due to the general economic downturn, the decreasing share of energy-intensive industry and the lagging pace of restructuring of insolvent state enterprises, electricity demand has grown less than expected; the Asian crisis (1997/98) has aggravated things. The ratio of electricity-GDP growth has fallen further (see Table 1). The discrepancy between generation and consumption may eventually even produce a phenomenon new to the developing Chinese economy: *overcapacity*. Traditionally, a sellers market, power utilities are now facing the danger of being put up against competition by their clients and are struggling to keep all of their plants running. Temporary shutdowns — unheard of in former years — have been reported.

The development perspectives of the power sector are further clouded by the aggravation of fundamental structural problems that have haunted the country since the beginnings of large-scale electrification in the 1960s. The imbalances between resource-rich regions and electricity-consuming regions have grown over time. Power exchanges between producing and consuming regions are limited due to the segmentation of the grid: China consists of not less than seven inter-provincial and six provincial grids, most of which are not interconnected. *Coal*, the only relevant fossil fuel in the power sector, is available in the Northeast and the underdeveloped regions of the North and Inner Mongolia. Complex transport schemes are required to supply the consuming coastal regions in the East of the country.[1] Hydropower, once considered to be the way out of the shortage, is in fact facing the same dilemma, with resources concentrated in the centre of the country (Yellow and Yangtzi rivers with affluents), thousands of kilometres away from the electricity-hungry regions.[2] The structural imbalances are sometimes considered a technical issue that can be overcome by providing the required transport infrastructure (Todd, 1996). However, this additional infrastructure is also expensive and implies transmission losses, be it the new East–West railway corridor (Shenmu to Huanhua), the Yu-Wei slag pipeline from Shanxi to Shanghai, or additional high-voltage transmission lines from the Three Gorges and other inland power stations to the coast.

The "soft landing" of the power sector comes at a time when groundbreaking deregulation of the sector is for the first time being seriously considered by the government. Thus far, the sector has been dominated by state-owned monopolies at the Central and provincial levels. The abandoning of the branch Ministry for Electric Power has lead to a *de jure* separation between the management of the sector (State Power Corporation) and its regulation (Power Bureau within the State Economic and Trade Commission). The SPC is at the same time *de facto* owner *and* regulator of the sector. It conceives the country-wide development plans and approves all major new projects. It is also responsible for setting out the principles of cost accounting, where a duality between "socialist" and "capitalist" price calculations has emerged in recent years.[3] However, ambitious reform plans to liberalise the power sector have been adopted (Gao, 1999; Andrews-Speed and Dow, 1999). As a first step, a wholesale market is to be set up by 2005 with a single-buyer model to create competition between producers. In a second step, large consumers will be free to choose their

[1] Coal transports account for 40% of the total commercial rail transport. Transport costs account for about half of cif prices; for example Northern Chinese coal shipped to Shanghai costs about USD 40 per ton of coal equivalent, whereas Australian imported coal stands at about c.i.f. USD 25-30. *Gas* does not play a role in the national power system; gas production is marginal and it is locally concentrated. Similarly, *oil* resources, which are plentiful in the Northwest, are too far away from consumers to be commercially exploitable (Hirschhausen and Andres, 1999).

[2] Nuclear power has yet to prove its reliability in the Chinese context, with 2 GW of installed capacity and 7 GW under construction.

[3] Old power plants, dating from the socialist period and fully depreciated, only calculate variable costs (fuel) and fixed costs for personnel and maintenance). By contrast, power plants dating from the recent reform period and financed with loans — the so-called "capitalist plants" — have to include the capital costs and an appropriate return on investment in their costs. Thus, capitalist plants are about 20% more expensive than socialist ones, even though their thermal efficiency is higher and they pollute less. Thus, if direct competition was introduced without further regulatory adjustments, socialist plants would clearly out-compete capitalist ones.

Table 1
Economic development and energy consumption in China 1980–1998[a]

Year	GDP growth (%)	Primary energy demand (mn. t sce)	Primary energy demand growth (%)	Primary energy demand growth/GDP growth	Final electricity consumption (TWh)	Final electricity consumption growth (%)	Electricity demand growth/GDP growth	Nominal electricity price index (1980 = 100)	Real electricity price index (1980 = 100)
1980	7.8	602	1.0	0.1	276	2.2	0.3	100	100
1981	4.5	594	− 1.3	− 0.3	284	2.9	0.6	100	97
1982	8.8	620	4.4	0.5	302	6.3	0.7	100	94
1983	10.3	660	6.5	0.6	324	7.3	0.7	100	90
1984	14.6	709	7.4	0.5	349	7.7	0.5	100	86
1985	12.7	766	8.0	0.6	381	9.2	0.7	100	80
1986	8.3	808	5.5	0.7	417	9.4	1.1	110	84
1987	11.0	866	7.2	0.7	462	10.8	1.0	120	86
1988	11.0	930	7.4	0.7	509	10.2	0.9	133	78
1989	4.0	969	4.2	1.0	545	7.1	1.8	146	66
1990	5.2	987	1.9	0.4	580	6.4	1.2	169	84
1991	9.3	1038	5.2	0.6	632	9.0	1.0	189	99
1992	14.2	1092	5.2	0.4	702	11.1	0.8	207	106
1993	13.5	1160	6.2	0.5	781	11.3	0.8	277	149
1994	12.6	1227	5.8	0.5	866	10.9	0.9	316	138
1995	10.5	1312	6.9	0.7	928	7.2	0.7	320	98
1996	9.6	1390	5.9	0.6	999	7.7	0.8	366	119
1997	8.8	1420	2.2	0.2	1045	4.6	0.5	409	152
1998	7.8	1374	− 3.2	− 0.4	1072	2.6	0.3	446	193

[a]*Sources:* China Statistical Yearbook (1998), International Energy Agency "Energy Statistics and Balances of Non-OECD Countries (1995–1996)", BP Amoco "Statistical Review of World Energy (1999)", Wiesegart (1998); author's calculations.

suppliers directly; and finally, the retail market will be fully liberalised. The institutional separation between power generation and the network has already been introduced six pilot regions (Liaoning, Jinin, Heilongjian, Shandong, Zhejiang, Shanghai).

Deregulation and competition will put the power sector on a more solid economic basis, but they will also contribute to further destabilising the long-term planning targets. Given the threat of overcapacity and unknown effects of deregulation, the State Power Corporation has declared a general halt to new development projects.[4] The policy of putting the "large fire" (*da huo*) on hold is to be implemented against the will of provincial governments, who stand to lose their polluting, yet existing, power generation base (Hollander, 1997).

On the other hand, the official discourse continues to prescribe double-digit growth patterns of electricity consumption and corresponding plans of generation, transmission and distribution capacities. The 9th five-year plan requires a doubling of generation capacity from 270 GW (1999) to over 500 GW in 2010. Likewise, gross electricity production is supposed to increase from the current 1200 to 2500 TWh. However, given the upcoming structural changes in the power sector, it no longer seems useful to apply traditional, linear growth projections. The following three sections sketch out an alternative, hands-on approach.

3. Aggregate electricity demand to 2010

3.1. The model, data and assumptions

There are no established models for forecasting electricity consumption in China.[5] In the policy-oriented perspective that we adopt in this paper, the marginal gains from applying complex models in this context are limited. Therefore, we apply a simple Cobb–Douglas function as shown in Eq. (1), assuming constant income and price elasticities as well as an autonomous increase in energy efficiency (AEEI). While this is clearly a second-best solution, it can produce a set of results relevant to the current policy debate.[6]

$$E_{2010} = \left[\left(\frac{GDP_{2010}}{GDP_{1996}} \right)^{\alpha} \times \left(\frac{P_{2010}}{P_{1996}} \right)^{\beta} \times (1-\gamma)^{2010-1996} \right] \times E_{1996}, \quad (1)$$

where E_t is the Electricity consumption in t, GDP_t the gross domestic product in t, P_t the electricity price (relative to consumer price index) in t, α the income elasticity of electricity demand, β the price elasticity of electricity demand and γ the autonomous energy efficiency increase (AEEI).

The parameters are set upon plausibility considerations: the *income elasticity* of electricity demand (α) was below unity over the last seven years, with an average of slightly above 0.7, down from 0.8 for the 1980–1989 period. This trend corresponds to the decreasing energy-output ratio of the Chinese economy in the post-Mao reform period since 1979, when the energy use per unit of GDP fell by over 50%. The decreasing energy intensity has been explained by increasing technical efficiency, which more than compensates the effects of structural change (Garbaccio *et al*., 1999; Sinton et al., 1998). This result is in line with estimates for other countries in economic transformation, such as Poland and Hungary (Dobozi, 1988). The long-run elasticity is likely to be even smaller, as the renewal of the capital stock will accelerate the improvements in energy efficiency. We opt for an income elasticity of 0.7, but will run sensitivity analysis for higher and lower values.

The *price elasticity* (β) is more difficult to estimate. Energy price increases in China have been rather slow in the 1980s, and prices today are lower than they need to be in the future. Evidence from other transformation and developing countries suggests that demand can vary greatly with price variations, reaching absolute levels of -0.1 to -0.3 in the short run, and up to -0.7 or even -1 in the long run.[7] Based on these considerations, we hold a price elasticity of -0.2 to be realistic, and will run sensitivity analyses with other values. Nothing concrete is known on the *autonomous efficiency increase* of electricity consumption (γ), which is generally assumed to exist independently of price effects; it is estimated here at the usual 1% annually.

[4] Exemptions are only possible for so-called "clean coal technologies" (i.e. fluid circulation, desulphurization and denoxification equipment), for gas-fuelled power plants, combined heat-and-power units (CHP) and pump-storage plants. Older power plants, the thermal efficiency of which is about 30% lower than of new ones, are to be shut down earlier than originally scheduled.

[5] Estimating parameters of Chinese aggregate energy demand is already full of pitfalls. An attempt to forecast energy demand was undertaken by Chan and Lee (1996) using 1953–93 data in a cointegration and error-correction model. However, due to data problems and different levels of disaggregation, different research comes to different results on identical issues; the most recent examples are Garbaccio et al. (1999) and World Bank (1993), developing different reasons for China's falling energy-output ratio.

[6] We did run some regressions on price- and income elasticities of electricity demand between 1980 and 98, but the results were implausible and econometrically insignificant. Data going back to the Maoist period, that is pre-1979, can not be used due to the socialist nature of the economic environment at that time. The formula is designed according to Horn (1999).

[7] See Pesaran and Smith (1993), Horn (1999), according to which this approach is designed, and the discussion in Erdmann (1995): Chan and Lee (1996) estimated a price elasticity of -0.9 for aggregate energy demand in China.

We introduce between different scenarios in order to catch possible economic developments: scenario I ("high growth"), scenario II ("medium growth") and scenario III ("low growth"). These reflect different GDP growth rates and real price developments. Based upon a review of the existing literature on macroeconomic and institutional perspectives of the Chinese economy, our own discussions with managers and researchers of the Chinese energy industry, and considerations of plausibility derived from other studies, we make the following assumptions on the exogenous parameters:

GDP has been buoyant over the last decade, though voices challenging the sustainability of this growth path are increasing, not only in the wake of the Asian crisis.[8] Double-digit growth rates being unlikely in the medium term, a likely estimate for the high growth scenario seems to be 9% per year. On the other hand, should China catch a late Asian crisis contagion, including a banking crisis, instability of the exchange rate and so on, a lower value of about 4% is not overpessimistic. The medium growth scenario lies in between, at 6.5%;

Energy prices need to be increased in order to reach a minimal economic level, including full cost recovery and appropriate profitability.[9] Higher production efficiency can limit the required price increases only to a certain extent. It seems that all cost components are facing upward pressure: capital expenditures for modern new buildings, environmental standards, new transmission and distribution infrastructure; raw material costs (as long as domestic coal remains the dominant fuel); and profit payments, should the commercialisation and hardening of budget constraints proceed.[10] The higher the economic growth, the easier it will be to implement real energy price increases. A yearly increase of 3%, assumed for the medium-term growth scenario, would yield a relative electricity price increase of about 50% in the year 2010; this increase also seems to be a reasonable target to attain full cost recovery by 2010. Should economic growth be lower (scenario III), real price increases may be politically constrained, say to 2% p.a. On the other end, in the high growth scenario, rising living standards may lead consumers to require higher electricity standards, for example environmental protection, increased reliability, installed load, and other quality aspects. This requires more investments, and thus higher price increases. The price scenarios also include the risk of a devaluation, which would increase capital expenditure for about one-third of equipment (imports).

Three minor assumptions are made with respect to network and other losses, both of which are higher than in other developing countries. Should the modernisation of the sector proceed according to the principles set down by the government, then this is likely to lead to an above-average reduction of losses. Therefore, going beyond the exogenous efficiency increases already embodied in the model, we assume that network losses fall from the current 7% of gross production to 5%, and other losses (including own losses) fall from 15 to 12%. Exports and imports do not play any significant role; we assume the export share of gross production to be constant (0.4%). The reference year is 1996, that is the last year for which an energy balance according to IEA standards is available.

3.2. Results

Table 2a presents the full set of assumptions and results of the scenarios for aggregate final electricity consumption and gross production. In the medium-term growth scenario II, final electricity consumption in 2010 rises to about 1240 TWh, which is "only" 48% above the 1996 value, and gross electricity generation even rises less, due to increased efficiency in generation and distribution (39% to about 1500 TWh). In the low growth scenario, no. III, final electricity consumption increases only by 20% to 1000 TWh, which is even lower than 1996 gross production. The high growth scenario, no. I, implies an increase of final electricity consumption of about 81%. Though highly aggregate, the results already carry one important message: electricity demand in the year 2010 may be significantly lower than prescribed in the current official government plans. Even the results of the high growth scenario I (1831 TWh) are more than one-fourth below the 9th five-year plan, requiring 2500 TWh of gross electricity production in 2010. A comparison between these three scenarios and other institutions' forecasts is shown in Fig. 1.

The lower part of Table 2a shows the distribution of gross electricity production by generation source, and the *primary energy required* for this production. According to government plans, *coal* will remain the dominant source, with only a small decrease from 77% to about 70%. However, the projected increase in power plant efficiency (from 30% in 1996 to 35% in 2010) will reduce the requirements for primary coal as well. In the medium-growth scenario, primary coal requirements are

[8] Deutsche Bank Research, (various issues; and Fukasaku (1994). Taking an historical perspective on Chinese economic development, Maddison (1998) uses a 5.5% average compound growth rate until 2015 (4.5% per capita GDP growth, 1% population growth). Ho *et al.* (1998) use yearly GDP growth assumptions of 4.5%, 6,5% and 7.6% for the slow-growth, medium-growth and high-growth cases, respectively. The IMF has reduced its growth forecasts for the year 2000 to 6%.

[9] The average price of electricity of about 350–400 CHY/MWh does not cover total production costs; it is estimated that they need to be increased by 33–50% to attain cost recovery. For an overview, see Andrews-Speed *et al.* (1999).

[10] In 1997, the State Power Corporation, owning assets of CHY 742 bn, made a pre-tax profit of CHY 8.8 bn only, that is a return on equity of 1.2%, not much for a vertically integrated monopolist; see State Power Corporation (1998). Taking into account the unpaid bills of an estimated CHY 20 bn, SPC even makes losses.

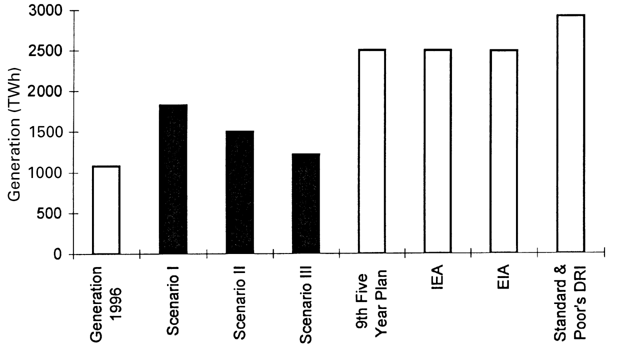

Fig. 1. Comparison of demand scenarios to 2010 with other forcasts. *Sources*: China Economic Information Net "Report on China's Energy Development"; Energy Information Administration "International Energy Outlook"; International Energy Agency "World Energ Outlook (1998)", authors' calculations

258 Mtoe, only 8% above 1996 requirements. This is in contrast once again with the official government plans, which forecast coal consumption for use in power plants of about 350 Mtoe.

A *sensitivity analysis* shows the results under different elasticity assumptions. For the sake of simplicity, the results are related to final electricity consumption of the medium-growth scenario only. Table 2b shows the relative deviations from the scenario II (medium growth) for the combinations of three different income elasticities and price elasticities; the index used in the scenario II (148, resulting from an income elasticity of 0.7 and a price elasticity of -0.2) is normalised to 100. The sensitivity analysis shows that the income elasticity is clearly the dominant variable: a reduction of the income elasticity from 0.7 to 0.5, holding the price elasticity constant, yields a 16% lower final electricity demand, whereas an increase of the income elasticity to 0.9 would increase final demand by 20%. Yet the highest possible deviation from our estimates (e.g. the combinations $0.5/-0.4$ at the lower extreme, $0.9-0.1$ at the higher end), do not change the findings significantly: even the results of the higher end (24% above the medium-growth scenario, or 1860 TWh) would still be about one-fourth lower than the official governmental forecast.[11]

4. Disaggregate electricity demand at the sectoral level

In order to broaden the scope of the scenarios, a *sectoral disaggregation* is introduced. Electricity intensities per value added differ between the sectors; hence different development paths will have different implications for electricity consumption. If, for example, the development of the service sector in the Chinese economy is as dynamic as often assumed, then electricity consumption would be much less affected than in the case of the traditional growth path based upon industrial development. The disaggregate model requires estimates of the development of the economic sectors, mainly industry as by far the largest consumer of final electricity (about two-thirds), but also of agriculture, the service sector and the residential sector. The Cobb–Douglas function is applied to each of the sectors individually, in order to obtain disaggregate electricity consumption. We make two further assumptions:

The *sectoral composition* of value-added. Given the expected structural change of the Chinese economy from an agricultural and heavy-industry based system towards high-tech and service activities, it seems reasonable to assume that the share of agriculture in GDP will decline; that the share of industry will decline as well, although somewhat less drastically; and that the share of the services activities, including transport, will increase. The speed of structural change will depend on the overall economic development: structural change will be facilitated in a high growth environment, whereas low growth tends to favour conservatism. We adopt the following two scenarios for structural change: scenario R for rapid structural change, and scenario S for slower change (Table 3). The basis of the structural scenarios is the medium- growth assumption of 6.5% economic growth and 3% increase of real electricity prices per annum.

We introduce a *differentiation of income elasticities*, based upon the idea that the acceleration of structural change in industry will lead to relatively lower consumption increases in this sector as compared to the agricultural or service sectors. This reflects the accelerated change within the industrial sector, from heavy industry to light- and high-tech industries. The difference between income elasticities between industry and other sectors is 0.1%. Likewise, we assume that income elasticities are lower in the scenario of rapid structural change.

For each of the sectors of the economy, an individual growth scenario is calculated, using the assumptions specified in Table 3. The growth of the residential sector is assumed to be similar to the overall growth of final electricity consumption, as calculated in the medium-growth scenario no. II.

The lower part of Table 3 presents the results of the disaggregate scenarios of final electricity demand for the year 2010, in index form with reference to 1996 and in absolute figures. The scenario of slow structural change (II-S) is almost identical with the above aggregate scenario II; the slightly higher share of services is compensated by a higher income elasticity assumed for the non-industry sectors. However, the scenario of rapid change (II-R) implies significantly lower final electricity

[11] Interestingly, the results of our high growth scenario converge with the forecasts made in China about 10 years ago. Lu (1993, p. 171) cites the plans made in the late 1980s: electricity generation by 2010 was assumed to be 1950 TWh.

Table 2
(a) Scenarios of aggregate electricity consumption to 2010

	Unit	1996	Scenario I rapid growth 2010	Scenario II moderate growth 2010	Scenario III slow growth 2010
Assumptions					
	GDP growth and electricity price inflation				
GDP	% p.a.		9	6.5	4
	Index	100	334	241	173
Real electricity prices	% p.a.		4	3	2
	Index	100	173	151	132
	Electricity demand coefficients				
GDP elasticity (α)			0.7	0.7	0.7
Price elasticity (β)			−0.2	− 0.2	− 0.2
AEEI[a] rate (γ)	%		1	1	1
Transmission losses	%	7	5	5	5
Plant requirements and other losses	%	15	12	12	12
Net exports	%	0.4	0.4	0.4	0.4
Results					
	Electricity consumption				
Final electricity consumption	Index	100	181	148	121
	TWh	835	1512	1238	1008
Transmission losses	TWh	77	92	75	61
Plant requirements and other losses	TWh	165	220	180	146
Net exports	TWh	4	7	6	5
	Gross electricity generation				
Electricity generation	TWh	1080	1831	1499	1220
	Gross electricity generation by source				
Coal	%	77	70	70	70
Oil[b]	%	4	4	4	4
Gas	%	0	3	3	3
Nuclear	%	1	3	3	3
Hydro	%	17	20	20	20
Coal	TWh	832	1283	1050	855
Oil[b]	TWh	43	73	60	49
Gas	TWh	3	55	45	37
Nuclear	TWh	14	55	45	37
Hydro	TWh	188	367	300	244
	Primary energy requirements				
Coal efficiency	%	30	35	35	35
Oil/gas efficiency	%	35	40	40	40
Coal	Mtoe	238	315	258	210
Oil[b]	Mtoe	11	16	13	11
Gas	Mtoe	1	12	10	8

(b) Sensitivity analysis of final electricity consumption[c]

Price elasticity	Income elasticity 0.5	0.7	0.9
− 0.1	88	105	124
− 0.2	84	100	120
− 0.4	77	92	110

[a]Autonomous Energy Efficiency Improvements.
[b]Predominantly used in coal power plants in the start-up phase.
[c]In %, calculated for scenario II (medium-growth)
Sources: Statistical Yearbook of China (1998); International Energy Agency "Energy Statistics and Balances of Non-OECD Countries (1995–1996)"; authors' calculations.
1 Mtoe = 11630 GWh.

Table 3
Disaggregate scenarios by sector: assumptions and results

	Unit	1996	Scenario II R rapid change 2010	Scenario II S slow change 2010
Assumptions				
	GDP shares			
Agriculture	%	17.5	12	16
Industry	%	49	46	48
Services, Transport, others	%	33.5	42	36
	GDP-growth (1996 = 100)			
Agriculture	Index	100	166	221
Industry	Index	100	227	237
Services, Transport, others	Index	100	303	260
Total	Index	100	241	241
	Income elasticities			
Industry			0.6	0.7
Other sectors			0.7	0.8
	Price elasticities			
All			− 0.2	− 0.2
Results				
	Final electricity consumption			
Agriculture	Index	100	114	151
Industry	Index	100	131	146
Services, Transport, others	Index	100	174	172
Residential[a]	Index	100	148	148
Total	Index	100	136	149
Agriculture	TWh	62	71	93
Industry	TWh	570	745	833
Services, Transport, others	TWh	90	156	154
Residential	TWh	113	168	168
Total	TWh	835	1139	1248

[a]Corresponding to the general electricity growth (Scenario II).
Sources: Statistical Yearbook of China (1998); International Energy Agency "Energy Statistics and Balances of Non-OECD Countries (1995–1996)"; authors' calculation.

consumption (about 1140 TWh). If this result were to be generalised, it would mean that the aggregate scenarios need to be corrected by about 10% downwards.

Industry will continue to dominate final electricity consumption, although its share will decrease from 68 to 65–67%. The fastest growing sector, that is services, will not even double its electricity consumption. The increase of the residential sector may eventually turn out to be higher than the estimated 48%, if residential and rural electrification proceed faster than planned, and the current bottlenecks in electricity distribution are eased.

5. Demand and supply at the regional level

China's power industry is not a homogenous block, but rather regionally diversified, with a very uneven distribution of resources, generation capacity and final electricity consumption. A regional disaggregation may therefore enhance the policy relevance of the scenarios further. Therefore, we also assess demand and supply to the year 2010 at the level of each of the 13 inter-provincial and provincial power grids:

Regional electricity *demand* depends on the 1997 level and on regional economic growth. The growth of each region is assumed to be a function of the average growth rate for the period 1994–1997. The rate of aggregate economic growth, i.e. the GDP-weighted average of regional growth rates, is 6.5% per annum, as specified in the medium-growth scenario (see Table 4a).

On the *supply side*, we assume that developments will proceed according to the governmental plans, but at a somewhat slower pace. Thus, capacity in 2010 will hover around 400 GW. The distribution of generation capacities among the regions, according to government plans, is shown in column 5 of Table 4b.[12] Assuming an

[12] 357 GW of the total capacity are already specified in large-scale power plant projects (State Power Corporation, 1998); we assume that the remaining 43 GW will be distributed according to the provincial share of total generation. The only exception is the Shandong provincial grid, for which we were able to verify a target of 25 GW, slightly above its current share.

Table 4
(a) Economic key figures for Chinese regions

Network	Provinces	GDP 1997 (Bill. CHY)	GDP-Growth p.a. (1994–97)	Composition of GDP 1997		
				Agriculture	Industry	Services, Transport, others
Northeast PN (NEPN)	Heilongjiang, Jilin, Liaoning, Inner Mongolia	875	9.5	18	51	31
North China PN (NCPN)	Shanxi, Hebei, Beijing, Tianjin	848	12.5	13	48	39
East China PN (ECPN)	Jiangsu, Shanghai, Anhui, Zhejiang	1735	14.5	15	52	33
Central China PN (CCPN)	Jiangxi, Hunan, Hubei, Henan	1225	14.0	25	45	30
Northwest PN (NWPN)	Qinghai, Gansu, Shaanxi, Ningxia	255	9.0	21	41	38
South China PN (SCPN)	Yunnan, Guizhou, Guangxi, Guangdong	1177	12.0	29	45	26
Fujian PG (FJPG)	Fujian	300	15.5	19	43	38
Shandong PG (SDPG)	Shandong	665	13.0	18	48	34
Sichuan & Chonqing PG (CYPG)	Sichuan, Chongqing	467	10.5	25	42	33
Hainan Provincial Grid (HNPG)	Hainan	41	5.0	37	20	43
Xinjiang Autonomous Region (XJAR)		105	9.0	27	39	34
Xizang Autonomous Region (XZAR)	Tibet	8	15.0	38	22	40
Hong Kong Administrative Region		1376	5.0	.	.	.

(b) Regional electricity generation and consumption by 2010

(1) Network	(2) GDP–growth p.a. (%)[a]	(3) Capacity 1997 (GW)	(4) Generation 1997 (TWh)	(5) Capacity 2010 (GW)	(6) Potential generation (Supply) 2010 (TWh)[b]	(7) Required generation (demand) 2010 (TWh)	(8) Electricity-surplus/-deficit (TWh) 2010
Northeast PN (NEPN)	5.4	31	143.0	47.5	213.75	177.7	+ 36.1
North China PN (NCPN)	7.1	34	176.5	51.0	229.5	253.5	− 24.0
East China PN (ECPN)	8.2	41.5	202.5	75.5	339.75	320.1	+ 19.7
Central China PN (CCPN)	7.9	36.2	159.0	67.4	303.3	245.4	+ 57.9
Northwest PN (NWPN)	5.1	15.7	70.0	21.4	96.3	84.9	+ 11.4
South China PN (SCPN)	6.8	43	164.3	63.4	285.3	228.1	+ 57.2
Fujian PG (FJPG)	8.8	7.3	29.0	12.4	55.8	48.1	+ 7.7
Shandong PG (SDPG)	7.3	16.5	83.9	25.0	2.5	123.4	10.9
Sichuan & Chonqing PG (CYPG)	5.9	12.6	58.1	21.4	96.3	75.8	− 20.5
Hainan Provincial Grid (HNPG)	2.8	15.7	3.4	1.7	7.65	3.4	142
Xinjiang Autonomous Region (XJAR)	5.1	1.9	10.2	2.1	9.45	12.3	− 2.9
Xizang Autonomous Region (XZAR)	8.5	0.2	0.3	0.2	0.9	0.4	+ 0.5
Hong Kong Administrative Region	2.8	10.6	36.4	11.0	49.5	36.2	+ 13.3
Total	6.5	266.2	1137	400	1800	1609	191

[a]adjusted with provincial GDP-Growth and GDP-Share (1997),
[b]average power plant duration of 4500h/year.
Source: China Statistical Yearbook (1998),
Sources: Electric Power Industry in China (1998), China Statistical Yearbook (1998), authors' calculations

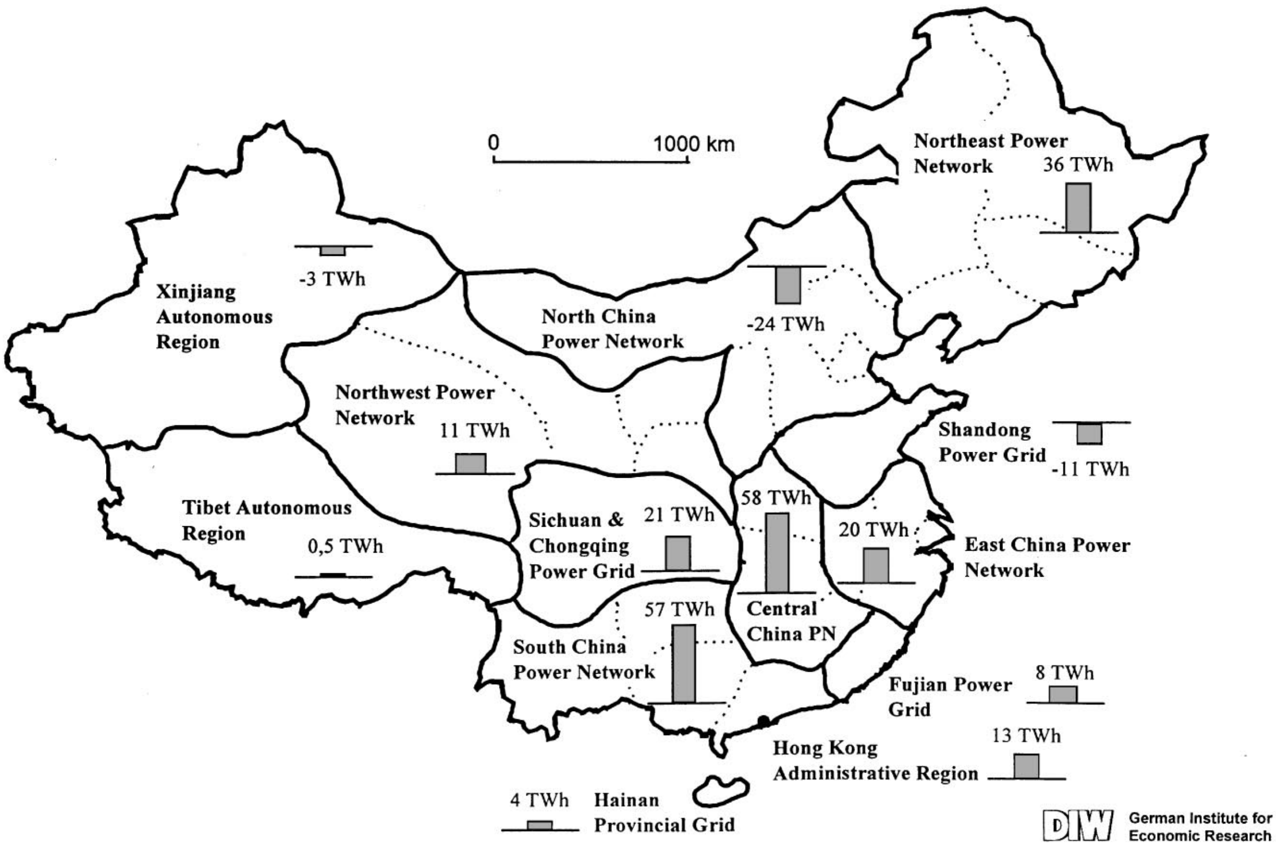

Fig. 2. Regional electricity surplus/deficit to 2010.

average yearly running-rate of 4500 h, we obtain the potential gross electricity generation in the year 2010.[13] The regional scenario does not take into account the interconnection projects that are only in a planning stage.

Table 4b and Fig. 2 show the results of the regional scenario to the year 2010: potential gross generation (supply, column 6), required generation (demand, column 7) and — as the difference between the two — likely overcapacities or shortfall of electricity in each of the 13 grids (column 8).[14] The results are counter-intuitive at first sight: the large industrial areas in the East of the country are likely to have *overcapacities* in 2010 (Eastern China Power Network, South China Power Network, Fujian, and Hainan Provincial grids, Hong Kong). However, this result can be explained by the particularly ambitious generation development projects in the industrial and commercial heartland of China. Similarly, the resource-rich, but less developed regions (Northeastern Power Network, Central China) have an ample supply. By contrast, North China, including the belt from Shanxi through Beijing to Tianjin, is likely to face undersupply, and may require imports or additional capacity. Not too much significance should be given to the results for the autonomous regions of Xinjiang and Xizang (Tibet), due to their marginal share in GDP and electricity consumption.

6. Conclusions

The scenarios indicate that the trend of fast growing electricity demand in China may be slowing down. Modest macroeconomic growth coupled with significant price increases will contain the Chinese power sector within limits well below the current governmental plans. Even with higher economic growth, structural change towards less electricity-intensive activities will support slower consumption increases. The figures of the 9th five-year

[13] 4500 h seems to be on the low side, but it corresponds to current utilisation rates (1997: 4613 h); it also takes into account the "natural" overcapacities required by regular maintenance work, etc. In this version of the scenario, we do not distinguish between different sources of electricity, in particular between coal and hydropower.

[14] The total gross electricity consumption in the regional scenario (Table 4b: 1609 TWh) differs from the one obtained in the aggregate scenario (Table 2b: 1499 TWh) for two reasons: the regional scenario is based upon 1997 date, efficiency gains are a lump-sum 5%. However, this difference does not change the message of the scenario.

plan seem to be overoptimistic. A revision of electricity demand projections seems necessary, including a critical analysis of future generation requirements and raw material consumption.

We have shown that under the current governmental development plans, some regions may face overcapacities by the year 2010. In particular, the industrial centres in the East of the country and along the seashore may be facing overcapacity. This is somewhat contradictory to other analyses implying that these regions may face power shortages in the medium term. If our estimates are right, then the current projects for inter-connection need to be revised: instead of creating high capacity AC- and DC-lines between Central China (Three Gorges, Ertan) and the coast, interconnection at the local level would suffice to increase supply security.

The great unknown is the future competition policy. If introduced at the level of electricity generation, competition is likely to imply an acceleration of the restructuring from older to modern power plans. However, a condition for this is that the government introduce measures to induce fair pricing, including capital costs for state enterprises and environmental (external) costs. High-cost coal producers and coal-based power plants stand to lose market shares. The social consequences have to be cushioned in order to ensure political support for reforms. A shift from quantitatively to more qualitatively oriented growth, including environmental aspects, is possible in China, but it requires a significant effort by the Central and Provincial governments to foster competition policies in the sector.

Acknowledgements

The authors thank Hans-Joachim Ziesing and Wolfram Schrettl for comments on an earlier version. Technical assistance: Wolfgang Härle and Deborah Bowen. The usual disclaimer applies.

References

Andrews-Speed, P., Dow, S., 1999. Reform of China's Electric Power Industry. University of Dundee, Mimeo.

Andrews-Speed, P., Dow, S., Wang, A., Mao, J., Wei B., 1999. Do the power sector reforms in China reflect the interests of consumers? The China Quarterly 158.

Hing, Lin Chan, Lee, Shu Kam, 1996. Forecasting the demand for energy in China. The Energy Journal 17(1), 19–30.

Dobozi, I., 1988. An empirical estimation of the price responsiveness of the Hungarian economy: the case of energy demand. In: Trends in World Economy. Hungarian Scientific Council for the World Economy, Budapest.

Deutsche Bank Research, various years. Country, Briefs Asia, China.

Erdmann, 1995. Energieoekonomik. Teubner, Stuttgart.

Fukasaku, K., 1994. China's Long March to an Open Economy. OECD Development Centre Studies, Paris.

Gan, L., 1998. Energy development and environmental constraints in China. Energy Policy 26(2), 119–128.

Gao, Y., 1999. Reform and Development of the State Power Corporation of China. Address to the 1999 China Business Summit, Beijing.

Garbaccio, R.F., Ho, M.S., Jorgenson, D.W., 1999. Why has the energy-output ratio fallen in China? The Energy Journal. 20(3), 63–91.

Hirschhausen, C., Andres, M., 1999. The Chinese energy industry at the eve of the 50th Anniversary of the People's Republic — the great flame put on hold. Economic Bulletin, 36(10).

Ho, M.S., Jorgenson, D.W., Perkins, D.H., 1998. China's economic growth and carbon emmissions. In: McElroy, M.B., et al. (Ed.), Reconciling Environmental Protection and Economic Growth. Harvard University Press, Cambridge, MA, pp. 301–341.

Horn, M., 1999. Energy demand in Ukraine to 2010. Energy Policy 27, 713–726.

Hollander, J., 1997. China and the New Asian electricity markts. The ERPI Journal 22(5), 24–30.

Lu, Y., 1993. Fuelling one billion — An Insider's Story of Chinese Energy Policy Development. The Washington Institute, Washington, DC.

Maddison, A., 1998. Chinese Economic Performance in the Long Run. OECD Development Centre Studies, Paris.

Pesaran, H., Smith, R., 1993. Alternative appraoches to estimating long-run energy demand elasticities: an application to Asian developing countries. DAE Working Paper No. 9308, University of Cambridge.

Sinton, J.E., Levine, M.D., Qingyi, Wang, 1998. Energy efficiency in China: accomplishments and challenges. Energy Policy 26(11), 813–829.

State Power Corporation, 1998. Electric Power Industry in China. China Electric Power Information Center, Beijing.

Todd, D., 1996. North-south energy resource transfers in China and the Port Intermediary. Tijdschrift vor economische en sociale gegrafie 87(3), 195–208.

Wiesegart, K., 1998. Die Stromversorgung in der VR China. Pacific Consult, Hirschberg.

World Bank, 1993. China: Energy Conservation Study. Report No. 10813-CHA, World Bank, Washington, DC.