Energy Conservation and Power Consumption Analysis in China Based on Input-output Method

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Abstract -- To achieve the sustainable development of society, the 11th five-year plan of national economic and social development of China raised the energy-saving target of decreasing 20% energy consumption per unit GDP in 2010 than the end of 2005, to what extent the power demand will be affected is the main problem to be solved when power industry polices are being made. Based on the input-output model, this paper sets high, moderate, extensive and 20% energy-saving scenarios to analyze energy-saving and power consumption situations of China in 2010.By computing, we get energy-saving level and power demand under different scenarios. The analysis results show that under the premises of adjusting the ratio of investment and consumption, optimizing products structure and improving energy efficiency, it is possible to achieve the energy-saving target. China's power consumption will maintain a stable growth trend during 2006-2010. The proportion of power consumption to the total will also increase during this period, and it is expected to reach over 17.5% in 2010.

Key-Words -- Input-output model; Improved RAS method: Energy intensity; Energy-saving; Power demand

I. INTRODUCTION

The 11th five-year plan of national economic and social development of China raised the target of decreasing 20% energy consumption per unit GDP in 2010 comparing with the level of 2005. Energy conservation will be an important task in the future. The implementation of energy-saving policies will promote the structure adjustment of industries and products, and affect the enhancement in efficiency of producing. It will also affect future power demand. It is an important subject to forecast the change of power demand in the future, plan power industry's development and save resources by taking the implementation of energy-saving policies into account.

The methods which are commonly used in power demand forecast are regression analysis, time series analysis, fuzzy prediction, neural network, grey theory, wavelet analysis, support vector machine, and so on[1]-[9]. Regression analysis can not reflect the impact of socio-economic development and macroeconomic policies such as energy-saving measures very well. Similarly, time series fails to depict the interrelationship between power demand and socio-economic influence elaborately. Since socio-economic development changes a lot in the future, fuzzy clustering prediction is hard to predict merely based on clustering of historical data. Neural network method has a powerful learning-based function, but it is actually a black-box simulation system, the specific expression of the mathematical model is not available, so it is hard to identify the interrelationship between power demand and each affecting factors clearly. Grey forecasting model needs comparatively less modeling information, and is easy to compute, but the result may get more inaccurate when the data is getting much greyer. This method is suitable for load forecast with exponential growth but not suitable for long-term prediction. Wavelet analysis performs well in short-term forecast, but it is not effective in long-tern forecast [7]. Up to now, there is not any mature power demand forecasting method which can comprehensively take the reform and development of economy and society, the change of residents’ consumption pattern, the adjustment of energy consumption structure and enhancement in efficiency which are brought by energy-saving policies into consideration.

The change of energy consumption structure and energy intensity, especially the change of power consumption structure and power consumption intensity is the key factor which will affect power demand in the future. There is a substantial amount of research on the analysis and decomposition of energy intensity change. Garbaccio (1999) used two revised input-output tables to analyze the reasons of energy intensity decline in China during 1978-1992, and he concluded that technological progress is the main reason for the energy intensity decline, while structural change increases the energy intensity [10]. Depend on 2500 energy-intensive firms' survey, Fisher-Vanden (2004) used Divisia decomposition analysis to analyze the energy intensity and came to the conclusion that rise in related products price, increase of research and development expenditure, reform of enterprise ownership and change in industrial structure are the specific factors which account for the rapid decline of energy intensity in China during 1997-1999[11]. Reference [12]-[14] did researches on energy consumption structure and intensity change of 1990s in China; they hold that the main reason for industrial energy demand decline is the decrease in real energy intensity. Reference [15] gave a scientific definition of energy intensity and energy efficiency, the analysis shows that structural adjustment contributed more than efficiency enhancement did in total decline of energy intensity during 1995-2005 in China. For the past few years, power consumption analysis has aroused more and more concerns. Wang (2005) decomposed electricity consumption intensity in Shanghai and gave some relevant suggestion [17]. Paul A. Steenhof (2006) decomposed industrial demand for electricity during 1998-2002 in China by Laspeyres index decomposition method [16]. But till now, there is not any systematic power demand forecasting method which can embrace the change in energy consumption structure, energy intensity and power consumption intensity, especially the influence of energy-saving policies in the future, and normal power forecasting models are incompetent to reflect the impact of energy conservation policies on power demand.

Based on input-output method which comprehensively incorporate the economic ties among departments, this paper set four different scenarios to analyze China's energy consumption and conservation situations in the "11th five-year plan" period. This paper furthers the analysis to forecast change in power demand on the completion of energy conservation target, which adequately reflect the impact of conservation target on power demand in the future. Compared to previous studies, this is a major breakthrough.

This paper is organized as follows. Section 2 introduces the main principle of input-output method and improved RAS method which is employed in the adjustment of direct consumption coefficients. Section 3 analyze the change of consumption structure and energy intensity based on China's input-output table of 2002, input-output method combined with scenario analysis is adopted to forecast power demand under each scenario. Section 4 presents the conclusions of the analysis which was carried previously, some policy recommendations are also put forward in this section.

II. INPUT-OUTPUT MODEL

A. Input-output Method

Input-output method is a quantitative analysis focus on the economic ties between different sectors, which study on national economic sectors' inputs and outputs balance by input-output table. An input-output table shows monetary interactions or exchanges between the economic sectors and therefore their interdependence. The rows of an input-output table describe the distribution of a sector's output throughout the economy, while the columns describe the inputs required by a particular sector to produce its output [20].

Suppose input-output table divides the national economy into *n* sectors, x_{ij} stands for the amount of the product of sector *i* absorbed as its input by sector *j*; Y_i is the final products that sector *i* provide; V_j stands for the total added value of sector *j* and X_i stands for the total output of sector *i*.

In the input-output table, each sector's intermediate use plus added value equals to the total input, and the total input in each sector equals to the total output. That is

$$X_j = \sum_{i=1}^{n} x_{ij} + V_j \tag{1}$$

Coefficient of direct consumption represents the production quantity of sector *i* which is used in the producing process of per product of sector *j*, generally we use a_{ij} to stand for it. The formula is

$$a_{ij} = x_{ij} / X_j \tag{2}$$

Direct consumption coefficient matrix consists of all direct consumption coefficients, which is noted as $A = (a_{ij})_{m\times n}$.

Leontief inverse coefficient matrix reflects the full demand both directly and indirectly to produce one unit final product, which is also known as full demand coefficient matrix. It is noted as

$$\bar{B} = (I - A)^{-1} \tag{3}$$

When we treat input-output relation from the perspective of total output, the formula is

$$AX + Y = X \tag{4}$$

From formula (4) we can get

$$X = (I - A)^{-1} Y \tag{5}$$

After defining vector Y which represents the full demand of each sector, we can get vector X which represents the total output of each sector by formula

(5).

B. Amendment of Direct Consumption Coefficient

The introduction of high-tech, the change of product mix and the effect of substitution will affect direct consumption coefficient to a certain extent in the future, so it's obviously necessary to amend the direct consumption coefficient to reflect all these influence. This paper adopts improved RAS method to adjust the direct consumption coefficient [20].

$$A = R \times A_0 \times S \qquad (6)$$

In formula (6), A_0 stands for direct consumption matrix of base year; A stands for direct consumption matrix of current; R stands for substitution multiplier matrix, and S stands for manufacturing multiplier matrix. Key coefficients will be adjusted according to specific situation [21] [22].

III. EMPIRICAL ANALYSIS

A. Data Sources

This paper carries on scenario analysis about energy-saving and power consumption situation in 2010 based on China's input-output table of 2002[23].

1. Scenarios and Conditions

According to each year's final product structure and its change to forecast the reasonable structure in 2010, finally we set high economic growth, moderate economic growth, extensive economic growth and 20% energy saving under high economic growth scenarios (hereinafter refer to S_1, S_2, S_3 and S_4 scenarios), the average annual GDP growth rate of each scenario are 9.5%, 8.5%, 9.5% and 9.5%.

With the implementation and become effective of macro-control measures, the ratio of capital formation will decline and the proportion of consumption should increase in future years. According to the final product structure during 1987-2002, this paper set the structure of each scenario as shown as Table 1.

Table 1 Final product structure of each scenario (%)

Scenarios	Consumption rate	Capital formation rate	Net export rate
High (S_1)	60	38	2
Moderate (S_2)	62	36	2
Extensive (S_3)	54.1	43.4	2.5
energy-saving (S_4)	61	37	2

We set the average level of energy efficiency enhancement according to "Special plans for medium and long term energy conservation in China"(SPEC) [24]. 20% energy-saving scenario adopt strengthened energy-saving target on the basis of SPEC, as shown as Table 2.

Table 2 Efficiency enhancement of each scenario (%)

Sectors/ scenarios	**S_1**	**S_2**	**S_3**	**S_4**
Textile	4.0	4.0	4.0	8.0
Nonferrous metals	4.5	4.5	4.5	10.0
Iron and Steel	6.0	6.0	6.0	8.0
Electric Power	8.0	8.0	8.0	13
Chemicals	8.0	8.0	8.0	15.0
Building Materials	8.0	8.0	8.0	12.0
Transportation	4.0	4.0	4.0	8.0
Other industries	1.0	1.0	1.0	4.0

2. Results of each scenario

Determining the final product vector Y of 2010 according to conditions of each scenario, we can get X of each scenario by formula (5). We can further get the intermediate input by formula (2), and finally we get the value added of each scenario. Then the industrial structure is available. Table 3 shows the industrial structure in 2010 of each scenario and Fig.1 reflect the change of industrial structure from 2005 to 2010.

Table 3 Industrial structure of each scenario (%)

Sectors/ scenarios	**2005**	2010			
		S_1	**S_2**	**S_3**	**S_4**
The primary industry	12.6	10.9	11.2	10.96	10.9
The secondary industry	47.5	44.8	44.4	49	44.3
Industry	42	39.2	39	42.6	38.9
Construction industry	5.5	5.6	5.3	6.3	5.4
The tertiary industry	39.9	44.2	44.5	40	44.6

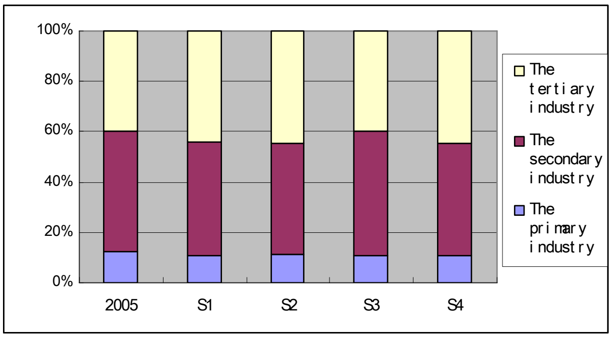

Fig.1 **Industrial structure in 2010**

The output of energy department reflects energy consumption of each scenario. Table 4 shows the energy consumption, total energy intensity in 2010 and energy-saving level compare to 2005 under each scenario.

Table 4 Energy consumption summary under each scenario (%) (2005 as the base year)

Sectors/ scenarios	2005	2010			
		S_1	S_2	S_3	S_4
Energy consumption (Gtce)	2.23	3.07	2.92	3.55	2.80
GDP (10^3billion Yuan)	18.3	28.8	27.5	28.8	28.8
Energy intensity (tce/10^4yuan)	1.22	1.07	1.06	1.23	0.97
Multiples of 2005	1.00	0.874	0.87	1.01	0.79
Energy saving (%)	0.00	12.6	13.0	-1.07	20.2

B. Power Demand Analysis under Energy-saving Policies

1. Development of China's Power Industry

Energy demand and power consumption inclines rapidly due to fast socio-economic development in China. As shown in Table 5, in the year of 2001, the power consumption was 1.47GWh, till 2005, the power consumption had increased to 2.5GWh, at an average annual increase of 13.2%. The ratio of power consumption in total energy consumption increased steadily and it had reached 14.38% in 2005.

Table 5 Proportion of power consumption to the total

Year	Power consumption (GWh)	Total energy consumption (Mtce)	Proportion (electrothermal equivalent)
1995	1.00	1261.82	9.77%
1996	1.08	1334.57	9.92%
1997	1.13	1332.04	10.42%
1998	1.16	1266.37	11.27%
1999	1.23	1290.06	11.73%
2000	1.35	1329.04	12.47%
2001	1.47	1367.18	13.25%
2002	1.65	1447.51	13.99%
2003	1.90	1683.14	13.91%
2004	2.20	1940.55	13.93%
2005	2.50	2233.19	14.38%

2. Power Demand Forecast in 2010

According to aforementioned input-output model, after getting the total output vector *X*, we can easily get power department's and energy department's total output, then we get the power consumption and the proportion of power consumption in total energy consumption, As shown in Table 6. We notice that the proportion of power consumption in total energy consumption will continue to rise in the future, this attribute to the factors such as electricity is a kind of clean energy, and China is now in the phase of electrification and so on.

Table 6 Power consumption forecast of each scenario

	Cons. (GWh)	Annual rate	Total energy consumption (Mtce)	Proportion electrothermal equivalent
2005	2.5	0.00%	2233.19	14.38%
S_1	4.45	12.2%	3073.15	17.80%
S_2	4.22	11.0%	2921.64	17.75%
S_3	4.96	14.7%	3554.07	17.21%
S_4	4.06	10.2%	2805.78	17.82%

C. Results Analysis

(1) We know that the average annual GDP growth rates of high, moderate, extensive and 20% energy-saving scenarios are 9.5%, 8.5%, 9.5% and 9.5%. Among them, the primary industry and secondary industry proportion of high, moderate and 20% energy saving scenario decline, while the tertiary industry proportion rises. As shown in Table 3, the proportion of the secondary industry declines from 47.5% in 2005 to around 44% in 2010, the proportion of the tertiary industry increases from 39.9% in 2005 to about 44% in 2010. This attributes to change in final product mix, increase of consumption and decline of capital formation. The extensive scenario strengthened the heavy structure. As a result, the proportion of the secondary industry inclines from 47.5% in 2005 to 49.02% in 2010, the proportion of the tertiary industry changes little.

(2) From table 7 we can see that high, moderate scenarios save 12.60% and 13.01% energy consumption in 2010 under scenario conditions, all failed to achieve 20% energy-saving target. Though energy efficiency enhanced the same level with high, moderate scenarios, the extensive scenario's energy intensity increases by 1.07% than that of 2005 owe to its heavy structure. This means the enhancement of energy efficiency is insufficient to offset the impact of upgrading heavy structure. The indicators of 20% energy-saving scenario such as average annual GDP growth rate, industrial structure are basically the same with high scenario, but this scenario enhance the energy efficiency, adjust the product structure on the basis of high scenario, results show that this scenario save energy consumption 20.21% than that of 2005.

(3) As is shown in Table 6, the demand for electricity reach 4.45GWh and 4.22GWh respectively under high, moderate scenarios and power demand rises at an average annual rate of

12.2% and 11.03%, by electro thermal equivalent, power consumption proportion to the total energy consumption reach 17.80% and 17.75% respectively. The power demand of extensive scenario increases rapidly due to its heavy structure, reaching 4.97GWh at an average annual increasing rate of 14.76%. Attribute to great enhancement in energy efficiency and adjustment of final product structure, the power demand of 20% energy-saving scenario is 4.07GWh, the average annual increase rate is 10.23%, this is no more than that of moderate scenario. This shows that under the conditions of enhancing energy efficiency and adjusting final product mix, we can expect a faster economic growth at the same power consumption.

IV. CONCLUSION

Through analysis about energy-saving level and power demand in 2010 under different scenarios, this paper gets the following conclusions.

Firstly, the energy-saving level under high and moderate scenarios are 12.6% and 13.01%, all failed to achieve 20% energy saving target. Under extensive scenario, industrial structure become heavier, the proportion of the secondary industry and industry rises to 49.02% and 42.6%. This leads to an incline of 1.07% in total energy intensity in 2010. To realize the target of 20% energy-saving, it is necessary to further adjust the final product structure, improve energy efficiency on the basis of high and moderate scenarios, and it is expected to save 20.21% energy consumption. It is of vital importance to change the extensive mode of economic growth characteristic of high input, high consumption and high pollution.

Secondly, controlling the investment scale, adjusting the investment structure, adjusting the industrial structure, controlling high energy consumption projects strictly, promoting the energy efficiency of sectors and divisions and reducing the export of products with high energy consumption are the necessary measures to realize 20% energy-saving target.

Thirdly, the demand for electricity reach 4.45 GWh, and 4.22 GWh respectively under high, moderate scenarios, power demand rises at an average annual rate of 12.22% and 11.03%. The power demand of extensive scenario increases rapidly due to its heavy structure, the power demand reaches 4.97 GWh and increases at an average annual rate of 14.76%. Attribute to great enhancement in energy efficiency and adjustment of final product structure, the power demand of 20% energy-saving scenario is 4.07 GWh, the average annual increase rate is 10.23%.

Furthermore, the proportion of power consumption in total energy consumption will continue to rise in the future years. It is expected to increase from 14.38% in 2005 to over 18% in 2010.

Finally, accelerate and optimize power supply and power grid construction are necessary measures to meet the growing demand of economic and social development for power, it is also an important part to realize the 20% energy-saving target in 2010.

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