Calculation of Energy Demand,Energy Structure and CO_2 Emissions in China(2010-2030)

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Abstract: - China is the country that emits most CO_2 in the world. As a developing country,China is undergoing urbanization and industrialization on an unprecedented scale,which need huge amounts of energy,and will emit more CO_2.We compute the migration population size based on rural and urban income gap and space discrepancy of the distribution of population and economic activities,and futher calculate the number of new residents in cities. What is more,taking Chinese industrial structure and energy consumption in each industry into account,we calculate energy consumption in the year 2010-2030.Considering energy consumption structure will be changed in the future,we simulate the CO_2 Emissions in different energy consumption structure. The conclusion is that CO_2Emissions can be reduced 1.95 billion tons in 2030 and if clear energy be utilized on a large scale.

Key-Words: - Urbanizaiton; Industrialization; Energy Demand; Energy Structure; CO_2 Emissions

1 Introduction

Chinese contributions to global CO_2 emissions are getting more important.According to the data of Energy Information Administration(EIA), China's CO_2 emissions from the Consumption and Flaring of Fossil Fuels is 6.02 billion tons in 2006,and exceeds the US in CO_2 emissions, which means China is the Number One CO_2 emitter. China is undergoing urbanization and industrialization on an unprecedented scale,which need huge amounts of energy,and will emit more CO_2.

Chinese urbanizaiton level increases from 17.92% in 1978 to 44.94% in 2007, and grows 0.93 percent per year,and it will stay at a rapid speed in the next 20-30 years.UN-Habitat says energy issue takes first place in the four challenges Chinese urbanization faces(they are energy issue、disposal of solid waste、monitoring system and information intercommunication for urban development). The gap between Chinese energy supply and demand is widening with the progress of urbanization and industrialization. China becomes a net-importer of petroleum from 1993. Imported oil takes 50% of domestic oil consumption in 2007. In 2008,China has imported 200.67 million tons(including crude oil、product oil、liquefied petroleum gas and others), up 9.5% over the same period of last year; and oil importing reliance reaches up to 52%.Common international practices show that, if oil importing reliance of a country reaches or exceeds 50%, it is in early-warning period.Moreover coal and electric power shortage from 2004 to 2006 and oil shortage as a result of high oil price in 2007 sound a warning to Chinese economic development and social stability again and again.

Chinese urbanization and industrialization are laid under restraint by energy supply. The effects they have on energy supply are multifactor,because population aggregation in cities needs more urban houses、road、all kinds of transportation、water、electric power and other infrastructure, which will increase demand for energy.Almost every main economy goes through a period of heavy and chemical industries during the mordenization process. For example, steel industry, building material industry, petrochemical industry, metallurgy industry, heavy machinery, railway and car industry, develop with abnormal speed,which are driven by surging demand because of urbanization. They are high-level capital and energy intensive industry,and lead to the fast rise in energy and maybe the insufficient energy supply. Whlie increased energy consumption lead to CO2 emission and climate change.China has suffered climate disaster in recently years.Overall,studing the relationship of urbanizaition, energy demand and CO2 emission quantificationally has the important realistic significance and is absolutely necessary in China at present.

2 Literature Review

Jones, D. W. (1991) realized that urbanizaition accompanied by the traditional agriculture transforming to the mechanization agriculture, the division of labor,the change of lifestyle,would increase the demand of energy[1]. Jyoti Parikh and Vibhooti Shukla' s used cross-national variations in urbanization and other development indicators to estimate a fixed-effects model of the determinants of energy usage. The same set of hypothesized determinants is then used to measure their contribution to estimated greenhouse gas emissions for the full set of countries[2]. Hiroyuki(1997) analysed multinational data from 1980 to 1993, finding that there were positive correlations between the urbanization rate and the logarithms of energy demand. If people's income increased, the energy consumption structure will change[3]. Energy-related CO_2 emissions account for about three-quarters of total anthropogenic CO_2 emissions. As a result, energy-related CO_2 emissions are the focus of many countries' current or planned policies and measures to limit emissions of greenhouse gases [4].Dzioubinski and Chipman (1999) analysed households energy consumption and drew a conclusion: households energy consumption transformed from organic fuel to commercial fuel,and the energy consumption ratio of household electric appliance increased gradually in the process of urbanization[5]. F. Urban, R.M.J. Benders and H.C. Moll (2007) noticed that energy systems of developing countries differ from those of industrialized countries,they present a model comparison of 12 selected energy models to test their suitability for developing countries. They concluded that to more adequately address the energy systems of developing countries, energy models have to be adjusted and new models have to be built[6]. Soytasetal(2007) and Ang, J (2008) used two nexus economic growth–environmental pollution nexus and economic growth–energy consumption nexus,into a single multivariate framework[7][8].

Geng Haiqing analysed the correlation of urbanizaition rate and coal, oil, natural gas consumption, found that correlation coefficient is higher than 0.9[9]. Gates and Yin (2004) found that the electric power consumption increased rapidly with urbanization[10]. F. Gerard Adams and Yochanan Shachmurove believed that China would import more and more coal,oil,natural gas in the future,and it was unavoidable.But if the energy efficiency can be increased, the shortage of energy can be catabatic[11]. Lei Shen maintained if energy efficiency remain the same,China could not attain the goal of modernization[12]. China should improve its energy efficiency, and need more clean erengy. Karine Fiore maintained that nuclear energy is very competitive and harmless to environment[13]. Ming Zhang (2009) analysed CO_2 emission in China from 1991 to 2006,found that Energy intensity effect is confirmed as the dominant contributor to the decline in CO_2 emission and CO_2 emission intensity, while economic structure and CO_2 emission coefficient effects are found to contribute little to the changes in CO_2 emission and CO_2 emission intensity[14].

Previous researchers acquired a great achievement on "economy-energy-environment".But most of them did not predict CO_2 emission in the future. On the basis of these literatures,we will establish "urbanization—energy—CO_2 emission" model. The system is multifactor and complex,so we establish the model with system dynamics.

3 Design Model

3.1 Modelling Procedures

Rapid growth of the energy consumption in China is ascribed to joint action of urbanization and industrialization. So it is necessary to estimate the urbanization rate,urban population and rural population. And industry structure should be considered also. Energy consumption in different industry are influenced by different socioeconomic factor,such as population,income,space distance,etc. In China Statistical Yearbook, final energy consumption can be roughly classified into seven categories:Industry,Farming,Construction, Transport and Storage Services, Wholesale and Retail Trade, Residential Consumption,other. We need to find the relationship of them with various method,for example,regression, factor analysis. Then we can get total energy consumption. According energy structure, every type energy consumption can be calculated. When coal,oil and natural gas burn,they emit CO_2 in different amount, so CO_2 Emissions from the Consumption of different energy should be calculated separately.

The system dynamics model is shown in Fig.1

3.2 Calculate Urbanization Parameter

How to estimate urbanization rate, urban population and rural population? Keyfitz Nathan, a well-known demographer, put forward a population migration model as follows:

$$\begin{cases} \dfrac{dP_r(t)}{dt} = (r-m)P_r(t) \\ \dfrac{dP_u(t)}{dt} = mP_r(t) + uP_u(t) \end{cases} \qquad (1)$$

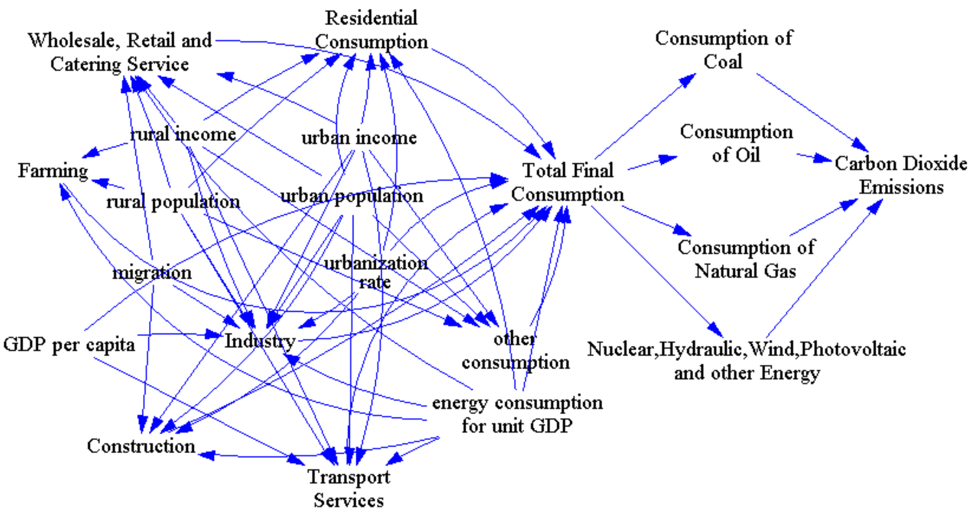

Fig.1 The System Model of Energy Demand, Energy Structure and CO2 Emission

In which $P_r(t)$ and $P_u(t)$ are the population at time t of the rural and urban areas respectively, r and u are the natural increase rates of the rural and urban areas respectively, a net outmigration rate from rural and urban regions taken as a constant fraction m of the rural population. Keyfitz model has important significance in theory. It describes general law of population migration from rural to urban areas.

The solution of this model is:

$$\begin{cases} P_r(t) = P_r(0)e^{(r-m)t} \\ P_u(t) = \dfrac{mP_r(0)}{r-m-u}\left(e^{(r-m)t} - e^{ut}\right) + P_u(0)e^{ut} \end{cases} \qquad (2)$$

Define function $\Phi(t)$, the urbanization rate, thus

$$\Phi(t) = \frac{P_u(t)}{P_r(t) + P_u(t)} \qquad (3)$$

4 Calculate CO_2 Emissions

Total final energy consumption can be calculated with above-mentioned method. Energy structure of every year can be found in *China Statistical Yearbook*. Now we calculate CO_2 Emissions in two methods.

4.1 CO_2 Emissions when energy structure remain unchanged

Energy structure in China changed little in recently years(Fig.2). In 2007,Coal accounts for 69.5% in Chinese energy consumption, petroleum 19.7% and gas 3.5%. Nuclear power,hydropower and wind power sum up to 7.3%. Suppose energy structure keep the same in the future,the consumption of every kind of energy can be calculated. And with the data of table 1 and table 2,CO_2 emission of every kind of energy can be calculated too.

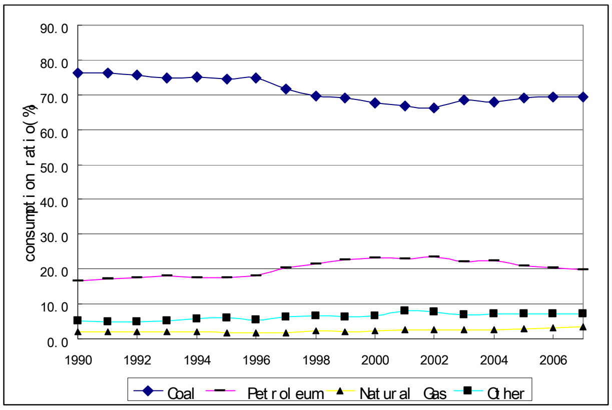

Fig.2 Energy Structure in China

Table 1 CO_2 Emission From the Consumption of Fossil Fuel

Fuel	Coal	Crude oil	Natural Gas
Potential CO_2 emission factor (Kg $CO_2/10^6$KJ)	24.78	21.47	15.30

Sources :Workgroup 3 of the National Coordination Committee on Climate Change(Xue,1998)

Table 2 CO_2 Emission From the Consumption of Clean Energy

Sources: Report of the French Ministry of Finance and Economy, 2003,www.cea.fr.

4.2 CO_2 Emissions when the proportion of clean energy rise

Now China is taking measure to reduce the ratio of fossil fuel(especially coal). Clean energy will be used more and more. In 2007,China formulates *Programming of the medium and long term development of nuclear power and renewable energy.*The following specific goals are expected to reach under the sustained energy development strategy: energy consumption of unit GDP will be reduced by 20% on the level of the end of the 10th five-year plan; primary energy demand will be less than 2.5 billion tons of standard coal by 2020, saving 0.8 billion tons; coal consumption ratio is controlled under 60%, nuclear power ratio will be increase to 4% . In ord to cope with the challenges of the world financial crisis,China modified the programming of the development of nuclear power.It is estimated that nuclear power will reach 60GW in 2020,and accounts for 5% in total energy consumption . Renewable energy utilization reaches 525 million tons standard coal (power generation by renewable energy stands at 100 MW); oil importing reliance is controlled under around 60%; the reduction rate of main pollutants is 45%-60%.So nuclear power and renewable energy can accounts for more than 20% in total energy consumption. Logistic repression model can describe the change of clean energy structure. Then we can get the energy structure in China (2010-2030) as Fig.3.

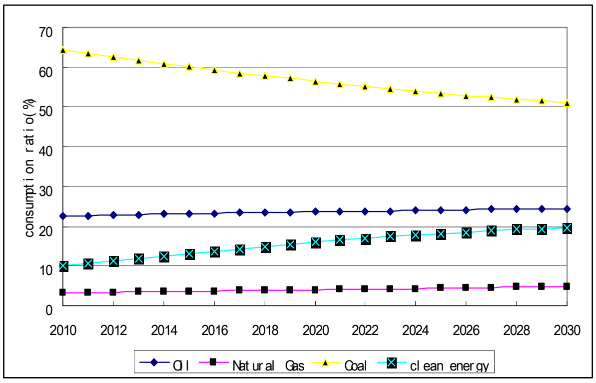

Fig.3 Energy Structure in China(2010-2030)

From table 2 we can know why clean energy will help human to reduce CO_2 emission. Compare with coal and oil, hydraulic and nuclear power nearly emit zero CO_2.

5 Result

Run the simulation model of system dynamics with

Energy	Hydraulic	Nuclear	Wind	Photovoltaic
CO_2 Emissions (g/kWh)	4	6	3-22	60-150

*Vensim software.*The output is following :

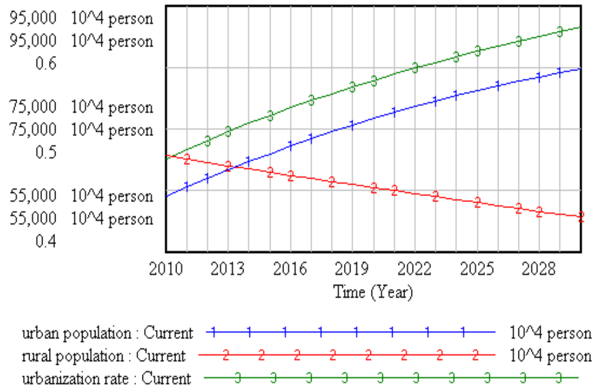

Fig.4 Urbanization Parameter in China(2010-2030)

It can be found from Fig.4 that the population will keep increasing in urban areas but decreasing in rural areas. Urban population exceeds rural population in 2013. The urbanization rate in China will be reach 58.3% in 2030 if the trend goes on. As the rural population decreases, the size of migration will fall down, from more than ten million in 2010 to merely five million in 2030; the increase speed of the urbanization rate decreases from 0.8% per year down to 0.4% per year.

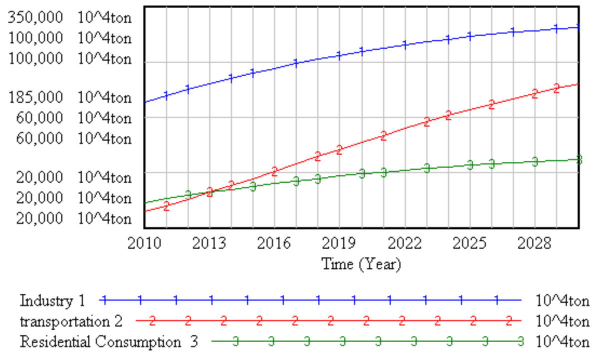

Fig.5 Energy Demand of Industry,Transportation and Residential Consumption

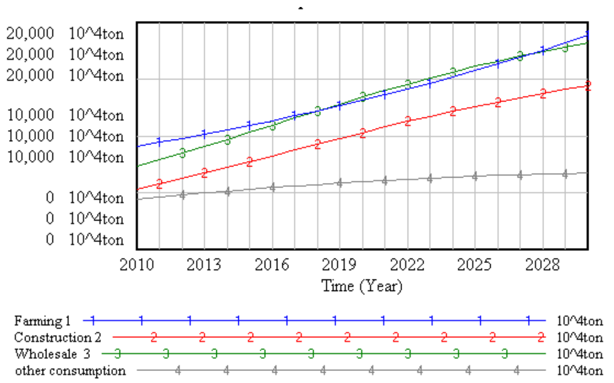

Fig.6 Energy Demand of Farming,construction, Wholesale and Retail Trade, other consumption

Simulation results of energy demand of different industry are shown in Fig.5 and Fig.6. Energy consumption of industry makes greatest contribution to the final energy consumption, but because of transformation of heavy chemical industry and technology advancement, energy consumption of unit GDP will decrease gradually and then the growth rate of industry energy consumption will decline. As a result of rural labor going to the urban areas, the agriculture needs more machinery which causes rapid increase in energy. This conforms to general law of mutual replacement between capital and labor in economics.

Urbanization will give impetus to the massive urban infrastructure and houses construction, and so huge amounts of steel,cement and other materials are needed. To take 2007 for an example, China's GDP accounts for just 6% of the world total', but steel consumption more than 30% and cement about 55%. What is more, demand for high energy consumption industries is inelastic in Chinese urbanization progress. Increased urban population and resident's income accelerate the popularization of durable goods, such as electrical household appliances and family cars and others, also lead to rapid increase in energy demand. Energy demand of the wholesale、retail and catering industry and others also keep rising , but the growth is relatively low.

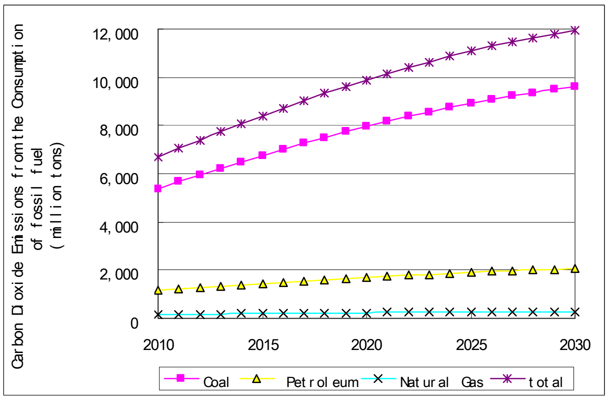

Fig.7 CO_2 Emissions when energy structure remain unchanged

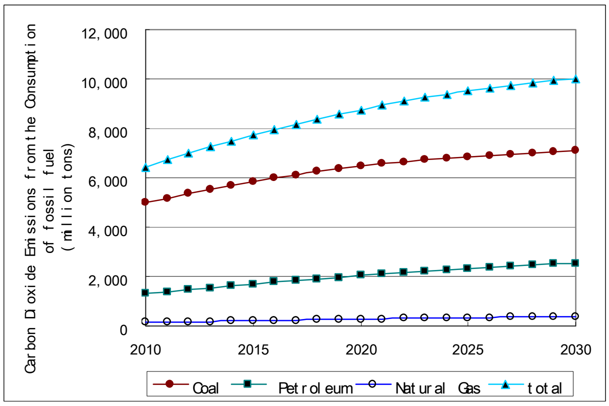

Fig.8 CO2 Emissions when the poportion of clean energy rise

Predicting on the basis of the present energy consumption pattern, China needs more than 5.32 billion tons standard coals in 2030.In Fig.7, when energy structure remain unchanged, CO_2 emission will be 9.89 billion tons in 2020 and will be 11.96 billion tons in 2030. If the ratio of clean energy reach 20% in 2030(as Fig,3), while the ratio of coal falls to 50%,then CO_2 emission will be 10.01 billion tons(Fig.8,), which means CO_2 emissions can be reduced 1.95 billion tons by optimizing the energy structure.

6 Conclusion

As the largest developing country and the largest CO_2 emitter, China's energy consumption has important implication for global climate change. If China does not adopt the sustainable development energy strategy, in the near future, the energy mining, transformation and utility will have great influence on the environment, the public health, the CO_2 emission and world climatic change, the economic development, state energy security and so on. Therefore, Chinese energy consumption structure must be adjusted considerably, the proportion of the coal should be reduced and the ratio of nuclear power ,hydropower, solar and wind power will be advanced. Given its effect on the ecological environment, Chinese hydropower resources exploitation should not increase sharply. Wind and solar energy utilization are developing very quickly, but the percentage of wind and solar energy capacity is fairly low. So in the long run, enhancing the proportion of nuclear power is thought of as practical.

Energy economization is as important as optimizing the energy structure. The price of energy is controlled by government in China, and is not

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determined by market conditions. The price of energy is low because the aim of the government is to stabilize economies and to prevent inflation. But on the other hand, the low price of energy is going against energy economization, and lowers the efficiency of energy utilization. In 2005,China's energy consumption per unit GDP is 2.7 times the world's average level, 4.6 times high-income countries. Lower utilization efficiency leads to over consumption of energy, and pollute the environment badly. So it is necessary to increase energy price gradually, narrow the gap between actual price and theoretical price (considering the environmental cost), establish and improve linking price mechanism between fossil energy and clean energy. Then , price of energy should determined by market conditions.

According to the *Framework Convention on Climatic Changes,* China is under no specific obligation to limit the emission of CO_2. However, as the largest green house gas emitter,China must take its responsibility for protection of the global climate, follows the principle of attaching equal importance to economization on energy and expansion of the energy industry, striving to raise its energy utilization efficiency and to readjust its energy structure, to reduce CO_2 emission.

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