# Systems Dynamics of Future Urbanization and Energy-related $CO_2$ Emissions in China

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*Abstract:* - China is undergoing urbanization on the largest scale in the world, which need huge amounts of energy,and will emit huge amounts of $CO_2$ into atmosphere.Now China is the country that emits most $CO_2$ in the world. Urbanization means population migrate to city and town, which will increase sharply demand for energy and other resource.Considering the energy efficiency and energy structure in China,the situation will be extremely serious. The urbanization is caused by population migrating from rural to urban areas, which is promoted by the income gap between them. We compute the migration 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 and $CO_2$ Emissions 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 $CO_2$ Emissions can be reduced 1.95 billion tons in 2030 if clear energy account for 20% of total energy consumption.

*Key-Words:* - Urbanization; Energy Demand; Energy Structure; $CO_2$ Emissions; Systems Dynamics

## 1 Introduction

China 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. Energy-related $CO_2$ emissions account for 83% of total greenhouse gas emissions in China in 2004. 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 keep a rapid speed in the next 20-30 years. 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 relyed on the restraint of energy supply. The effects they have on energy demand 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 capital intensive and energy intensive industry, and lead to the fast rise in energy consumption and maybe the insufficient energy supply.

In order to reduce $CO_2$ emissions and protect natural environment,China need to improve energy efficiency,and optimize the energy structure. Due to the natural endowment of resources and the increasing demand for the world market, China has an enormous task of deploying clean and less-carbon technologies. It need covers both mitigation and adaptation technologies. Now, more and more renewable energy is being exploited. Nuclear energy is regarded the substitute for fossil fuel especially coal. Increased energy consumption lead to $CO_2$ emissions and climate change.China has suffered climate disaster in recently years. Overall, studing the relationship of urbanizaition, energy demand and $CO_2$ emissions 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 et al (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 et al(2007) used two nexus economic growth–environmental pollution nexus and economic growth–energy consumption nexus,into a single multivariate framework[7][8]. Hai et al(2008 ) compare with pricing decision of two stages ecological industry chain,which is consisting of manufacturer and retailer, mainproduct buyer and byproduct buyer was considered[9]. Kong et al(2008) analyzed renewable energy,point out the problem of wind power,continuous fluctuation of wind speed and direction, and wind energy conversion systems are of strong nonlinear characteristics for many uncertain factors,so wind power could not be substitute for fossil energy on large scale[10]. Akram Avami et al(2008) find transportation sector has dominant effect in air pollution in Iran, so the efficiency of traffic from the structure of the system should be promoted[11]. Nathalie Pessel et al(2008) presents a Principal Component Analysis study for greenhouse system modelling. The results obtained on a experimental greenhouse system are efficient[12]. Shuichi Ashina et al(2008) focused on $CO_2$ emissions of residential sector released in Japan They examine the economics of energy efficiency strategies, for reducing $CO_2$ emissions from the perspective of regional characteristics[13]. Nasser Ayoub et al (2009) pointed out that policy making for sustainable development and public interest involves wicked problems,the problems are characterized with lack of clear and definitive problem formulation, different value judgments and uncertainties[14].

Geng Haiqing(2004) analysed the correlation of urbanizaition rate and coal, oil, natural gas consumption, found that correlation coefficient is higher than 0.9[15]. Gates and Yin (2004) found that the electric power consumption increased rapidly with urbanization[16]. 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[17]. Lei Shen maintained if energy efficiency remain the same,China could not attain the goal of modernization[18]. China should improve its energy efficiency, and need more clean erengy. Karine Fiore(2006) maintained that nuclear energy is very competitive and harmless to environment[19]. Ming Zhang (2009) analysed $CO_2$ emissions in China from 1991 to 2006,found that Energy intensity effect is confirmed as the dominant contributor to the decline in $CO_2$ emissions and $CO_2$ emissions intensity, while economic structure and $CO_2$ emissions coefficient effects are found to contribute little to the changes in $CO_2$ emissions and $CO_2$ emissions intensity[20].

Previous researchers acquired a great achievement on "economy-energy-environment"system.But most of them did not predict $CO_2$ emissions 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

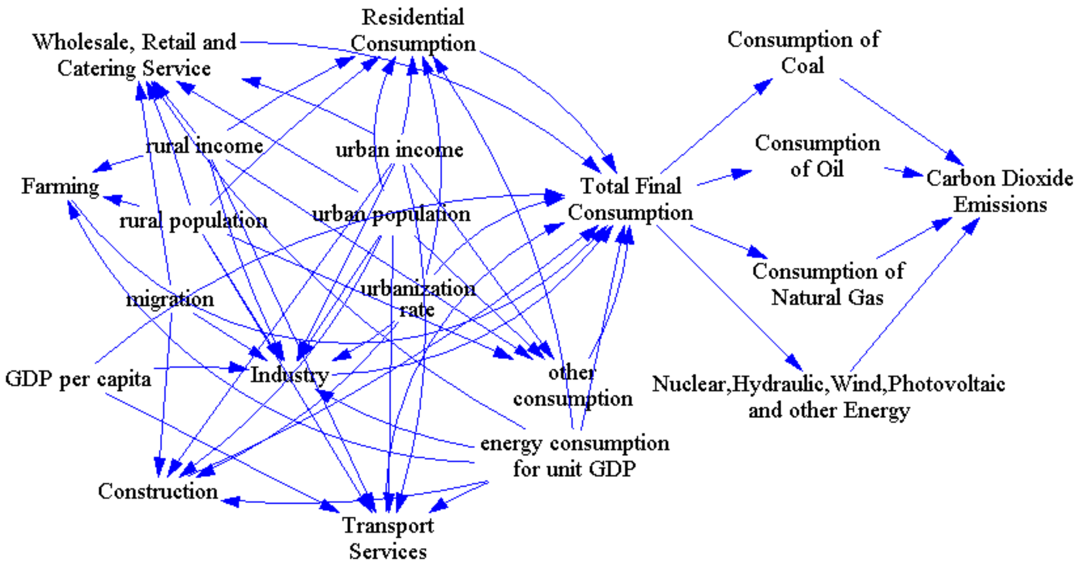


Fig.1 The System Model of "Urbanization-Energy-$CO_2$ Emissions"

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,daily consumption, 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, principal component 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 Urbanization Model

How to estimate urbanization rate, urban population and rural population? Keyfitz Nathan, a well-known demographer, put forward a population migration model as follows[21]:

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

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:

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

The solution of this model is:

$$\begin{cases} P_r(t) = P_r(0)e^{(r-m)t} \\ P_u(t) = \dfrac{mP_r(0)}{r-m-u}\left(e^{(r-m)t} - e^{ut}\right) + P_u(0)e^{ut} \end{cases} \tag{3}$$

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

$$\Phi(t) = \frac{P_u(t)}{P_r(t) + P_u(t)} \quad (4)$$

Keyfitz model describes general law of population migration from rural to urban areas.But the assumption of constant rate of natural increase and migration rate is very harsh.So the application of this model is limited. In fact natural increase and migration rate are not constants and they are influenced by social economy.So we will establish systems dynamics model to analyse parameters influence each other. $r$, $u$ and $m$ vary with time, so they can be denoted by $r(t)$, $u(t)$ and $m(t)$ in systems dynamics model. The change rate of rural population is directly proportional to rural population base,while the change rate of urban population is influenced by urban population and migration population.

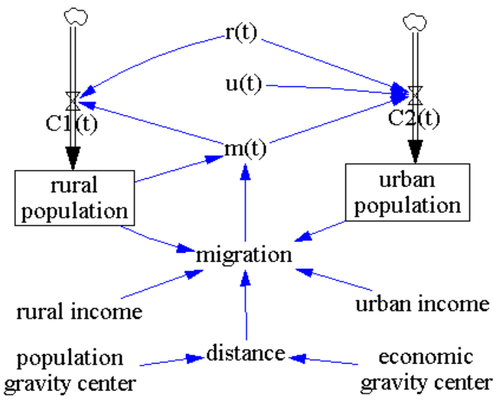


Fig.2 Urbanization and migration model

$r(t)$ and $u(t)$ can be calculated in demographic multi-factor theory,while $m(t)$ can be computed according to migration size every year. Spacial distance($D$) between population gravity center and economic gravity center in the future will be deduced by extrapolation. Migration size and Spacial distance will be deduced as following methods.

Most of migration is caused by socioeconomic factor. So the income gap between urban and rural areas must be considered. Also, the more surplus rural labour,the more they migrate into urban areas. With the urbanization going on, population in rural areas decreases and the proportion of the urban population increases.When urban population proportion reaches certain degree,the speed of urbanization will slow down. So migration size can be seen as directly proportional to rural population and inversely proportional to urban population. On the basis of the original form, the gravity model can be modified as:

$$M_{ru} = K\frac{P_r W_u D}{P_u W_r} \quad (5)$$

where $M_{ru}$ is migration size from rural to urban areas, $K$ is constant coefficient, $W_r$ and $W_u$ are income in the rural and urban areas respectively in China, $P_r$ and $P_u$ are rural population and urban population, $D$ is spacial distance between population gravity center and economic gravity center of China.

$$\begin{cases} X^{k+1} = \dfrac{\sum_{i=1}^{n} \dfrac{m_i x_i}{\sqrt{(x_i - x^k)^2 + (y_i - y^k)^2}}}{\sum_{i=1}^{n} \dfrac{m_i}{\sqrt{(x_i - x^k)^2 + (y_i - y^k)^2}}} \\ Y^{k+1} = \dfrac{\sum_{i=1}^{n} \dfrac{m_i y_i}{\sqrt{(x_i - x^k)^2 + (y_i - y^k)^2}}}{\sum_{i=1}^{n} \dfrac{m_i}{\sqrt{(x_i - x^k)^2 + (y_i - y^k)^2}}} \end{cases} \quad (6)$$

Gravity center is a point at which torque is least in physics. On a two-dimensional Cartesian coordinates system, gravity center can be determined with equation (6).In regional economic research,suppose a region is composed by secondary region, then gravity center of certain attribute of this region can be calculated with equation(7):

$$\begin{cases} X = \sum (M_i \cdot X_i / \sum M_i) \\ Y = \sum (M_i \cdot Y_i / \sum M_i) \end{cases} \quad (7)$$

where $X$ and $Y$ are longitude and latitude of gravity center of certain attribute of a region respectively, $X_i$ and $Y_i$ are longitude and latitude of gravity center of certain attribute of a secondary region respectively.And in this paper, $X_i$ and $Y_i$ are defined with geographical coordinates of capital cities of provinces in China. Regard GDP as economic attribute when we make certain economic gravity center.Also regard population at the end of the year as population distribution attribute when we make certain population gravity center.

After obtain gravity center of economy and population,we can calculate the distance between them with follow equation:

$$D = N \cdot \left[ (C_s - P_s)^2 + (C_k - P_k)^2 \right]^{1/2} \quad (8)$$

where $D$ is spacial distance between population gravity center and economic gravity center , $P_s$ and $P_k$ are longitude and latitude of population gravity center; $C_s$ and $C_k$ are longitude and latitude of economic gravity center. Transform geographical coordinates(unit:degree)into the corresponding value to plane distance, denotes with $N$. Here $N$ equals 111.11Km per degree[22].Calculate with population and gross domestic product of every provinces in China according to *Statistics Yearbook of China* (1997-2008). The result of calculation is as table 1 and table 2.

Table 1 Distance between population gravity center and economic gravity center in China

| year | population gravity center | | economic gravity center | | distance (Km) |
|---|---|---|---|---|---|
| | longitude | latitude | longitude | latitude | |
| 1996 | 113.40 | 32.62 | 115.05 | 32.73 | 183.65 |
| 1997 | 113.45 | 32.59 | 115.10 | 32.71 | 183.70 |
| 1998 | 113.44 | 32.58 | 115.14 | 32.73 | 188.79 |
| 1999 | 113.43 | 32.57 | 115.18 | 32.73 | 194.61 |
| 2000 | 113.46 | 32.52 | 115.21 | 32.76 | 195.86 |
| 2001 | 113.42 | 32.54 | 115.22 | 32.77 | 201.17 |
| 2002 | 113.41 | 32.54 | 115.19 | 32.72 | 198.51 |
| 2003 | 113.41 | 32.53 | 115.20 | 32.71 | 199.77 |
| 2004 | 113.41 | 32.50 | 115.17 | 32.72 | 197.12 |
| 2005 | 113.47 | 32.50 | 115.17 | 32.76 | 190.64 |
| 2006 | 113.48 | 32.50 | 115.15 | 32.76 | 188.65 |
| 2007 | 113.48 | 32.50 | 115.14 | 32.75 | 187.22 |

Sources: Calculate according to the data from *Statistics Yearbook of China(1997-2008).*

Table2 Calculate coefficient $K$ in the model.

| Year | urban popu. ( $10^4$ ) | rural popu. ( $10^4$ ) | Urban Income (yuan) | rural Income (yuan) | $D$ (Km) | $K$ ($10^4$ /Km) |
|---|---|---|---|---|---|---|
| 1996 | 37,304 | 85 085 | 4839 | 1926 | 183.7 | 1.671 |
| 1997 | 39,449 | 84,177 | 5160 | 2090 | 183.7 | 1.815 |
| 1998 | 41,608 | 83,153 | 5425 | 2162 | 188.8 | 1.861 |
| 1999 | 43,748 | 82,038 | 5854 | 2210 | 194.6 | 1.821 |
| 2000 | 45,906 | 80,837 | 6280 | 2253 | 195.9 | 1.873 |
| 2001 | 48,064 | 79,563 | 6860 | 2366 | 201.2 | 1.860 |
| 2002 | 50,212 | 78,241 | 7703 | 2475 | 198.5 | 1.870 |
| 2003 | 52,376 | 76,851 | 8472 | 2622 | 199.8 | 1.929 |
| 2004 | 54,283 | 75,705 | 9422 | 2936 | 197.1 | 1.791 |
| 2005 | 56,212 | 74,544 | 10,493 | 3255 | 190.6 | 1.961 |
| 2006 | 57,706 | 73,742 | 11,759 | 3587 | 188.7 | 1.456 |
| 2007 | 59,379 | 72,750 | 13,786 | 4140 | 187.2 | 1.777 |

Sources: *Statistics Yearbook of China(1997-2008).*

The last column in table 2 is coefficient $K$ of every year.The value of $K$ fluctuates between 1.456 and 1.929, frequency between 1.81 and 1.88 is most,so it can be regard as a constant. This result indicates that the modified gravity model is consistent with the fact. Compute the average of the year1996-2007,it is $1.832 \times 10^4$person/Km. So the modified gravity model is

$$M_{ij} = 1.832 \frac{P_i W_j D_{ij}}{P_j W_i} \qquad (9)$$

### 3.3 Energy Efficiency

Energy efficiency is one of the key indexes affecting energy consumption demand. China's energy consumption per capita GDP is 2.7 times the world's average level, 4.6 times high-income countries in 2005.Lower efficiency leads to over consumption of energy, and wastes produced worsen the environment. Outline of the *Eleventh Five-year Plan* (2006-2010) on National Economy and Social Development of the country sets a goal to reduce its energy consumption per unit of gross domestic product gradually. Furthermore,in the Comprehensive Task Scheme on Energy Saving and Emissions Curbing of the state council, it is set forth that energy consumption for every ten thousand Yuan of GDP will decrease from 1.22 tons of the standard coal in 2005 to less than 1.0 ton in 2010, decreasing about 20%. It can be foreseen that energy consumption per unit of domestic gross product will continue to fall after 2010 which has been shown by existing time series data. Exponential function model can effectively depict this law of the curve sloping down(Fig.3), suppose $t = 1$ in 1999,the equation is:

$$y = 6.6528 t^{-0.625} \quad R^2 = 0.9625, F = 385.34$$

Energy consumption per unit of GDP in the future(2010-2030) will be deduced by extrapolation.

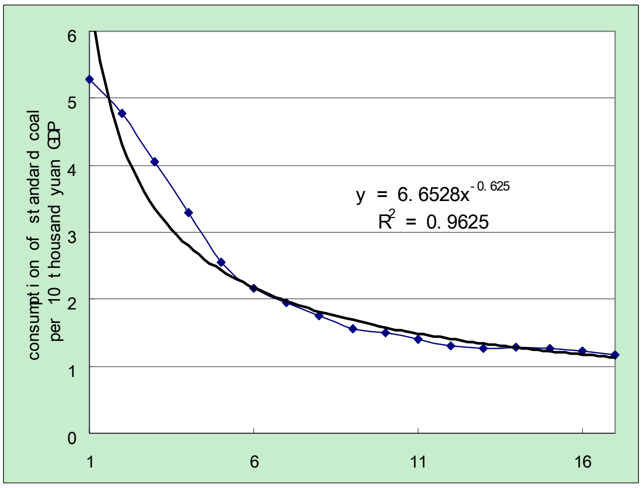


Fig.3 Change of energy efficiency in China

### 3.4 Energy Structure

Total final energy consumption and $CO_2$ Emissions can be calculated with the System Dynamics Model of “Urbanization-Energy- $CO_2$ Emissions”. Now we calculate $CO_2$ Emissions in two scenario: one is $CO_2$ Emissions when energy structure remain unchanged; the other is $CO_2$ Emissions when the proportion of clean energy rise.

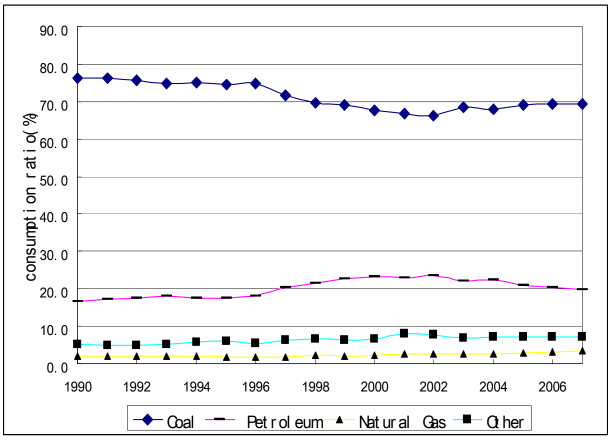


Fig.4 Energy structure in China

Energy structure in China changed little in recently years(Fig.4). 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(average of 2004-2007) in the future,the consumption of every kind of energy can be calculated. And according to the data of table 3 and table 4,$CO_2$ emissions of every kind of energy can be calculated too.

Table 3 $CO_2$ Emissions from the consumption of fossil fuel

| Fuel | Coal | Crude oil | Natural Gas |
|---|---|---|---|
| Potential $CO_2$ emissionsfactor (g /$10^6$KJ) | 24 780 | 21 470 | 15 300 |

Sources:Workgroup 3 of the National Coordination Committee on Climate Change[23]

Table 4 $CO_2$ Emissions from the consumption of clean energy

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

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

From table 3 and table 4 we can know why clean energy will help human to reduce $CO_2$ emission. Compare with coal and oil, hydraulic and nuclear power emit very little $CO_2$.

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 put forward *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 11th 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 order to cope with the challenges of the world financial crisis,China modified the programming of the development of nuclear power. It is planed 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 reaches 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 (hydropower,wind power and Photovoltaic) can accounts for more than 15% in total energy consumption in 2020,and 20% in 2030. Logistic repression model can describe the change of clean energy structure. Then we can get the energy structure in China (2010- 2030) as Fig.5

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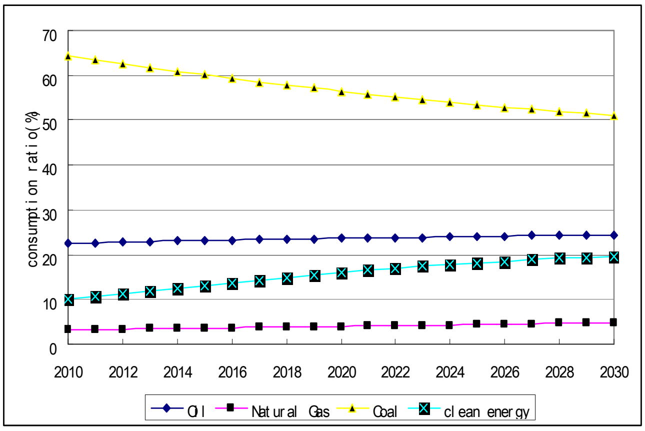


Fig.5 Energy Structure optimization in the future

### 3.5 Economic Development Scenario

China economy developed rapidly recently 30 years,and GDP per capita increased more than 8% annually. The speed may decrease in the future. In the economy plan of China,GDP per capita in 2020 will quadruple the 2000 volume. Chinese GDP per capita in 2000 is 7858 Yuan (RMB), so the goal is to reach up to 31432 Yuan in 2020. In order to realize it, average annual growth must keep 7.2%, but in fact, it is impossibly increasing by the same percentage in the next 20 years. Data of GDP per capita from 1995 to 2006 can be described by regression model,and the best regression model is the logistic equation. It is:

$$y = (u^{-1} + \beta_0 \beta_1^{\,t})^{-1} \tag{10}$$

In which $t$ is the future year, $y$ is the GDP per capita in predicted year, $u$ is the upper limit value, $\beta_0$, $\beta_1$ are model parameters.

China's economy will increase slower in 2020-2030. Suppose GDP per capita in 2040 double that for 2020(average growth rate is 3.5% annually), and then GDP per capita every year is fitted into the logistic regression equation(Fig.6). The income of urban and rural residents can be computed by the similar method.

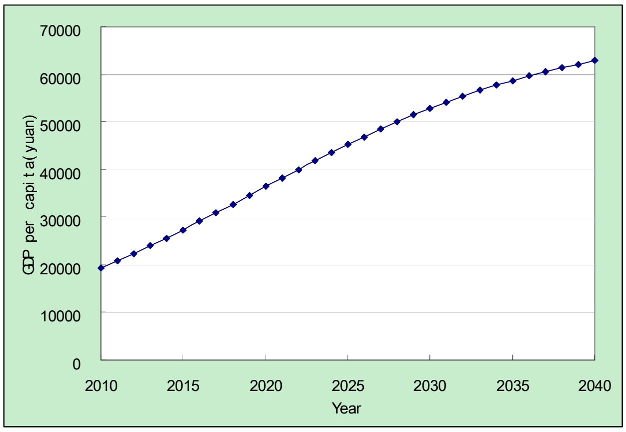


Fig.6 GDP per capita in the future

## 4 Result

Run the simulation model of System Dynamics Model of "Urbanization-Energy- $CO_2$ Emissions" with *Vensim software*.The output is following :

Table 5 Urbanization Parameter in China

| Year | Rural Population ( $10^4$ ) | Urban Population ( $10^4$ ) | Urbanization rate |
|---|---|---|---|
| 2010 | 70,755 | 64,118 | 47.5% |
| 2011 | 70,132 | 65,578 | 48.3% |
| 2012 | 69,551 | 67,000 | 49.1% |
| 2013 | 69,000 | 68,381 | 49.8% |
| 2014 | 68,463 | 69,708 | 50.5% |
| 2015 | 67,937 | 70,982 | 51.1% |
| 2016 | 67,421 | 72,208 | 51.7% |
| 2017 | 66,917 | 73,389 | 52.3% |
| 2018 | 66,423 | 74,527 | 52.9% |
| 2019 | 65,931 | 75,615 | 53.4% |
| 2020 | 65,444 | 76,659 | 53.9% |
| 2021 | 64,956 | 77,654 | 54.5% |
| 2022 | 64,474 | 78,609 | 54.9% |
| 2023 | 63,993 | 79,521 | 55.4% |
| 2024 | 63,509 | 80,386 | 55.9% |
| 2025 | 63,027 | 81,212 | 56.3% |
| 2026 | 62,549 | 82,002 | 56.7% |
| 2027 | 62,074 | 82,758 | 57.1% |
| 2028 | 61,604 | 83,481 | 57.5% |
| 2029 | 61,135 | 84,169 | 57.9% |
| 2030 | 60,670 | 84,827 | 58.3% |

It can be found from table 5 that the population will keep increasing in urban areas but decreasing in rural areas. Urban population exceeds rural population in 2014. 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.

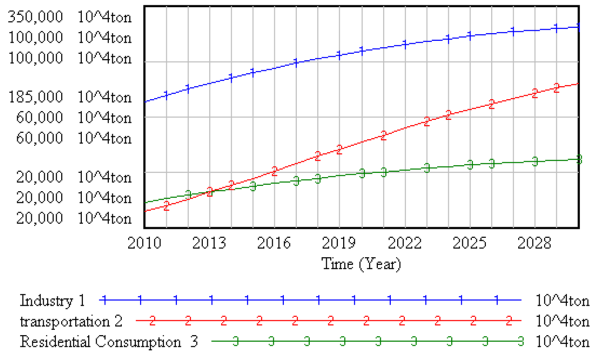


Fig.7 Energy Demand of Industry,Transportation and Residential Consumption

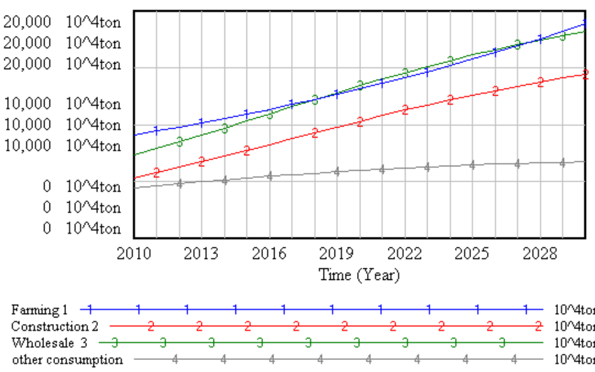


Fig.8 Energy Demand of Farming,construction, Wholesale and Retail Trade, other consumption

Simulation results of energy demand of different industry are shown in Fig.7 and Fig.8. 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 consumable, 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 rate is lower.

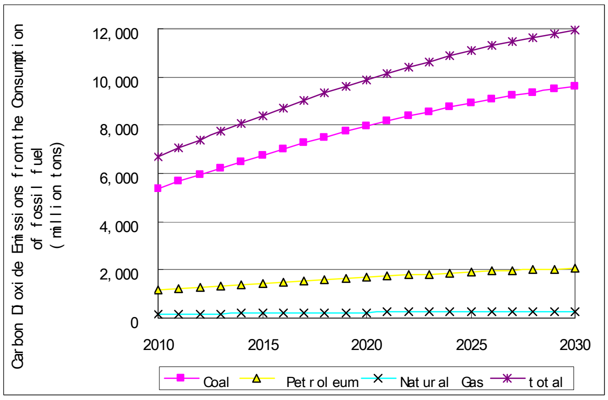


Fig.9 $CO_2$ Emissions when energy structure remain unchanged

Predicting on the basis of the present energy consumption pattern, China needs more than 5.32 billion tons standard coals in 2030.In Fig.8, when energy structure remain unchanged, $CO_2$ emissionswill 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,5), while the ratio of coal falls to 50%,then $CO_2$ emissionswill be 10.01 billion tons(Fig.10), which means $CO_2$ emissions can be reduced 1.95 billion tons by optimizing the energy structure.

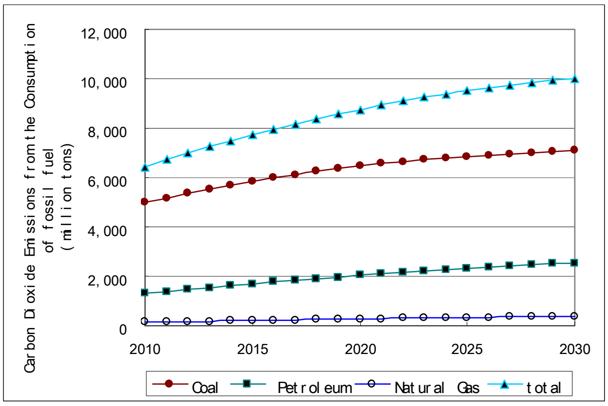


Fig.10 $CO_2$ Emissions when the ratio of clean energy rise

# 5 Further Discussion

Urbanization and industrialization in China are limited by the city environmental capacity,so the energy consumption and $CO_2$ emissions are limited. Chinese cities have been confronting with the acute shortage of water and land, and energy consumption continues to grow rapidly. What is more, the problems such as traffic congestion,water and air pollution and garbage disposal are tormenting persistently most of cities in China. It is believed that the increased population per year in Beijing can form a medium-sized city. The increasing city size is bringing heavy pressure on ecological environment. Although the urbanization is an inexorable law governing social and economic development, China, as the first in terms of the world's most population nations, has been facing more complicated ecological problems than other countries. In view point of sustainable development, the cities can accommodate limited amount of migration. Considering its natural environment,economic development and public service, the city can determines its size of population.

On the other hand, this model analyses the urbanization on the basis of mathematical demography and development economics theories,while policy effect is not taken into account. In fact, migration from rural to urban areas is obviously influenced by the policy factor in China. The progress of the urbanization is greatly accelerated since China relaxed limitations on peasants taking up permanent or temporary jobs in cities in the mid-1980s. For the moment the household registration system still exists and there are wide gap between the cities and countries in terms of infrastructural facilities,educational opportunities and social security which will last a long time in the future. It needs to be further discussed what changes would happen to the population migration if China is going to liberalize the policies on migration from rural to urban area and improve the benefits of rural migrants workers and the public services for the rural people .

# 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 $CO_2$ emissions 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. The results on the role of nuclear power in carbon abatement suggest that massive carbon abatement depends mainly on the development of nuclear power, and if installed capacity of nuclear power can reach 500 GW, the $CO_2$ will be decrease 30%. There is a still big gap compared with developed countries. European nuclear power capacity accounts for 44.3% in the world total', and North America is 34.7% ,Asia-pacific is 19.9%. In terms of countries respectively, nuclear power capacity of America, French and Japan amounts to more than a half of total production(up to 57%). Overall, Chinese nuclear power has a broad developing space. As a clean and high effective energy, nuclear power development is one of the most important decisions for China which helps to increase energy supply, optimize energy structure and deal with climate change and nuclear power expansion should be key focus for energy strategy.

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

The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC), set greenhouse gas emission mitigation commitments for industrialized countries, and the protocol did not set an explicit greenhouse gas reduction obligation for developing countries, including China. But $CO_2$ emissions in China influences the effect of international community's work for greenhouse gas reduction obligation.So China must take its responsibility for prevention of the global climate change, encouraging economization on energy, striving to raise its energy utilization efficiency and to optimize energy structure, to reduce $CO_2$ emission.

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