Integrated Input-Output Accounting for Natural Resources-Energy-Economy-Environment

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Abstract: For any kind of economy activity in today's human society, one important factor which cannot be ignored is the energy. It may be said that there is no human beings' today's development without energy. However, most environmental issues does appear as energy be used in human activities, e.g. acid rain formation, green house gas increasing by using fossil fuels, and un-renewable resources exhaustion by the corresponding primary energy overused, etc..

In this case, one kind of theoretical Integrated Input-output Table, in which the energy be especially considered, be designed on the basis of our Integrated Input-output Accounting Framework of Natural Resources-Economy-Environment[6] [7], and the relevant Input-output models be also set up, in this paper.

As application, one new and concrete Energy-Natural Resources-Economy-Environmental Input-Output Table—Chinese '92 Energy-Economy-Environmental Input-Output Table be put forward in this paper, and scenario forecasting and analysis for Chinese energy-resources-economy-environment (1992-2020) be given, too, in light of Chinese 1992 Input-output Table (Value), Chinese Statistics Year Book, Chinese Energy Balance etc..

Keywords: Input-output Accounting, Energy, Scenario Analysis

Input-output Accounting for Natural Resources-Energy-Economy-Environment[1]

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For any kind of economy activity in today's human society, one important factor which cannot be ignored off is the energy. It may be said that there is no human beings' today's development without energy. However, most environmental issues does appear as energy be used in human activities, e.g. acid rain formation, green house gas increasing by using fossil fuels, and un-renewable resources exhaustion by the corresponding primary energy overused, etc.. In this case, it's necessary to consider the energy especially in the framework of natural resources-economy-environment analysis, and set up an new integrated analysis model. On the basis of our integrated input-output accounting system of natural resources-economy-environment [6] [7], one new input-output accounting system for linkage analysis of energy-natural resources-economy-environment be set up, and scenario forecast and analysis for Chinese energy-resources-economy-environmental situation (1992-2020) be also made in our research.

1.Input-Output Accounting Table for Natural Resource-Energy-Economy-Environment Accounting

In our former work, one kind of input-output accounting table of natural resources-economy-environmental was designed as following [6],

Output / Input	Resource Recovery Department	Production Department	Pollution Abatement Department	Final Products	Total Output
Resource Used	u^e_{ij}	u^p_{ij}	u^w_{ij}	Y^e_i	X^e_i
Production Product	q^e_{ij}	q^p_{ij}	q^w_{ij}	Y^p_i	X^p_i
Pollution Emission	e^e_{ij}	e^p_{ij}	e^w_{ij}	Y^w_i	X^w_i
Value-added	N^e_j	N^p_j	N^w_j		
Total Input	Z^e_j	Z^p_j	Z^w_j		

(where u^e_{ij} -- the amount of resource i consumed by resource recovering department j; q^e_{ij} -- the amount of products of production-department i consumed by resource recovering department j; e^e_{ij} -- the amount of pollution i emitted by recovering department j; N^e_j--the value-added (labor wage, net social income, etc.) created by resource recovering department j (including the depreciation in fixed assets); Y^e_i -- the amount of consumption of resource i in final products; X^e_i -- the total amount of consumption of resource i; Z^e_j -- the total amount of recovery of resource j; u^p_{ij} -- the amount of resource i consumed by production-department j; q^p_{ij} -- the amount of products of production-department i

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consumed by production-department j; e^p_{ij} -- the amount of waste material i emitted by production-department j; N^p_j -- the value-added created by production-department i; Y^p_i -- the final product of production-department i; X^p_i -- the total product of production-department i; Z^p_j -- the total consumption by production-department j, equals to X^p_j in values; u^w_{ij} -- the amount of resource i consumed by pollution abatement department j; q^w_{ij} -- the amount of products of production-department i consumed by pollution abatement department j; e^w_{ij} -- the amount of waste material i emitted by pollution abatement department j; N^w_j -- the value-added created by pollution abatement department j; Y^w_i -- the amount of emission of pollutant i in the final products; X^w_i -- the total emission of pollutant i; Z^w_j -- the total amount of management of pollutant j)

This table is one kind of physical-value mixed input-output table in which the "input/consumption" consists of three parts:

1) Physical resource input (usage)/consumption (physical unit). It is classified according to the kinds of natural physical resources-used (e.g., coal, petroleum, nature gas, forests etc.) and indicated by the amount of physical resources exhaustion/usage in the process of human economy activities;

2) Production input/consumption (monetary unit). It's just the same as the input in the traditional input-output table, which consists of medium products input and primary input (e.g. salaries, depreciation of fixed assets, taxes, operation surplus);

3) Environmental resource input (damage)/consumption (physical unit). It is classified according to the kind of pollutants-emitted (e.g., CO_2 , SO_2, No_x ,etc.) and indicated by the amount of pollutant-emitted in the process of human economy activities.

From the row of the table, the "department" are extended from the traditional single productive department to the one which contains of three different departments, i.e. the department of resource-recovery, the department of production and the department of pollution-abatement. Here, the department of resource-recovery is classified by the corresponding kind physical resources used in the process human economy activities. Each department corresponds to one concrete kind of resources used. The production department's classification is just the same as that of the traditional table. The department of pollution-abatement is classified by the corresponding kind of pollution emission in the process of human economy activities. Each department corresponds to one concrete pollution emitted. Correspondingly, final output and total output in the new input-output table are also consists of three parts: the first part(corresponding to resource usage/consumption) and the third part (corresponding to pollution emission) are separately indicated by the amount of resource used/consumption and pollution emission in the final products field and the whole process of human economy activities, and the second part is indicated just same as indicated in the traditional table as before.

In order to combine our input-output table of natural resources-economy-environmental with the energy production and consumption, we divided further the traditional production/industrial department/sector into three parts: 1) primary energy department; 2) second energy department; 3) the others department, and the corresponding input is also divided into three parts: 1) primary energy product; 2) second energy product; 3) the others products. Now, an input-output table which integrated resource-energy-economy-environmental are designed as following (table 1).

Table 1

Output / Input	Resources Recovery Dept.	Primary Energy Dept.	Second Energy Dept.	Other Prod. Dept.	Pollution Abatement Dept.	Final Products	Total Output
Resource Used	u^{e}_{ij}	u^{p1}_{ij}	u^{p2}_{ij}	u^{p3}_{ij}	u^{w}_{ij}	Y^{e}_{i}	X^{e}_{i}
Primary Energy Products	q^{e1}_{ij}	q^{p11}_{ij}	q^{p12}_{ij}	q^{p13}_{ij}	q^{w1}_{ij}	Y^{p1}_{i}	X^{p1}_{i}
Second Energy Products	q^{e2}_{ij}	q^{p21}_{ij}	q^{p22}_{ij}	q^{p23}_{ij}	q^{w2}_{ij}	Y^{p2}_{i}	X^{p2}_{i}
Others Products.	q^{e3}_{ij}	q^{p31}_{ij}	q^{p32}_{ij}	q^{p23}_{ij}	q^{w3}_{ij}	Y^{p3}_{i}	X^{p3}_{i}
Pollution Emitted	e^{e}_{ij}	e^{p1}_{ij}	e^{p2}_{ij}	e^{p3}_{ij}	e^{w}_{ij}	Y^{w}_{i}	X^{w}_{i}
Value-added	N^{e}_{j}	N^{p1}_{j}	N^{p2}_{j}	N^{p3}_{j}	N^{w}_{j}		
Total Input	Z^{e}_{j}	Z^{p1}_{j}	Z^{p2}_{j}	Z^{p3}_{j}	Z^{w}_{j}		

(where u^{e}_{ij} -- the amount of resource i consumed by resource recovering department j; q^{ek}_{ij} -- the amount of products of k'th (k= primary energy products, second energy products, and the others products) production-department i consumed by resource recovering department j; e^{e}_{ij} -- the amount of pollution i emitted by resource recovering department j; N^{e}_{j}-- the value-added (labor wage, net social income, etc.) created by recovering department j (including the depreciation in fixed assets); Y^{e}_{i} -- the amount of consumption of resource i in final products; X^{e}_{i} -- the total amount of consumption of resource i; Z^{e}_{j} -- the total amount of resource j recovered; u^{pk}_{ij} -- the amount of resource i consumed by k'th (k= primary energy products, second energy products, and the others products) production-department j to produce corresponding k'th product; q^{pkl}_{ij} -- the amount of products of k'th (k= primary energy products, second energy products, and the others products) production-department i consumed by k'th (k= primary energy products, second energy products, and the others products) production-department j; e^{pk}_{ij} -- the amount of pollution i emitted by k'th (k= primary energy products, second energy products, and the others products) production-department j to produce corresponding k'th product; N^{pk}_{j} -- the value-added created by k'th (k= primary energy products, second energy products, and the others products) production-department i; Y^{pk}_{i} -- the final product of k'th (k= primary energy products, second energy products, and the others products) production-department i; X^{pk}_{i} -- the total product of k'th (k= primary energy products, second energy products, and the others products) production-department i; Z^{pk}_{j} -- the total consumption by production-department j, equals to X^{pk}_{j} in values; u^{w}_{ij} -- the amount of resource i consumed by pollution abatement department j; q^{wk}_{ij} -- the amount of products of k'th (k= primary energy products, second energy products, and the others products) production-department i consumed by pollution abatement department j; e^{w}_{ij} -- the amount of pollution i emitted by pollution abatement department j; N^{w}_{j} -- the value-added created by pollution abatement department j; Y^{w}_{i} -- the amount of emission of pollutant i in the final products; X^{w}_{i} -- the total emission of pollutant i; Z^{w}_{j} -- the total amount of pollutant j eliminated)

2. Basic Input-Output Table of China Design (92')

Based on Chinese 1992 Input-Output Table [2] and Chinese Statistics Year Book(1993) [3], we set up one concrete Energy-Economy-Environmental Input-Output Table (Appendix Basic Input-Output Table), in light of the above theoretical Energy-Economy-Environmental Input-Output Table .

In this new I-O table, there are,

1) three kinds of natural resources, that is, Coal, Petroleum and Natural gas (Units: 10000 ton);
2) five energy production sectors, that is, Coal mining and processing, Petroleum and natural gas extraction, Power generation steam and hot water production and supply, Petroleum processing, Coking gas and coal-related products (Units: million tons of oil equivalent);
3) thirteen non-energy production sectors, that is, Farming forestry animal husbandry fishery and water conservancy, Food beverage and tobacco, Textiles, Paper-making and paper products, Chemicals and allied products, Building materials and other, Smelting and pressing of metals, Machine building electric and electronic equipment, The others manufacturing, Construction, Transportation post and telecommunications services, Commerce food services materials supply and marketing and storage, Nonmaterial (the others services) production sectors (Units: 10000 RMB);
4) two kinds of pollution, that is, SO2, CO2 (Units: 10000 ton);

are included, but the natural resources recovery sectors and the pollution abatement sectors are not considered because of lacking of the relevant data.

3. Consumption Coefficient Matrix

On the basis of Appendix Basic Flow Input-Output Table, we obtain the synthesis direct and complete consumption coefficient matrix respectively, which includes four parts, that is, natural resources direct put in use coefficients, energy products direct consumption coefficients, non-energy products direct consumption coefficients, and pollution direct emission coefficients, as Appendix Direct Consumption Coefficient Table.

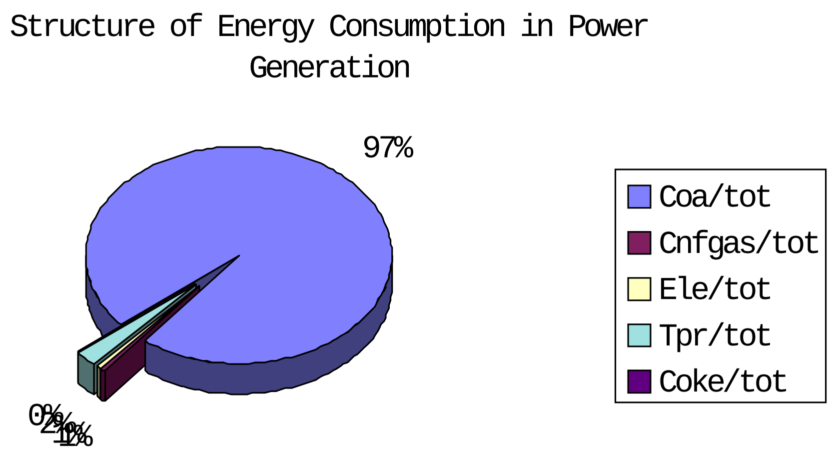
From the direct consumption coefficient matrix, on the natural resources used we can see , in 1992, about 600 ton of coal was used directly per output (million RMB Yuan) of Chinese Coal mining and processing sector's production, about 243 ton of petroleum and natural gas was used directly per output (million RMB Yuan) of Chinese Petroleum and natural gas sector's production, about 0.13 ton of coal and 0.012 ton of petroleum and natural gas used directly per GDP (million RMB Yuan).

On the environmental pollution emission, the Power generation steam and hot water production and supply sector is the first sector of SO2 and CO2 emission without consideration of the abatement in 1992, it emitted directly about 141 ton SO2 and 2378 ton CO2 per unit of output value (million RMB Yuan) which is over 97% of all SO2 emitted and over 93% of all CO2 emitted in the meanwhile. The second and the third are Petroleum processing sector and Coking gas and coal-related products sector respectively. They emitted directly about 106 ton and 41 ton CO2 and 0.23 ton and 2.44 ton SO2 per unit of output value (million RMB Yuan) respectively. Meanwhile, there are 0.03 ton SO2 and 0.55 ton CO2 be emitted directly per unit of GDP (million RMB Yuan) in1992.

And from the complete consumption coefficient matrix, we can see that the coal occupies an extremely proportion in the structure of energy consumption in power generation, it's nearly 97% in 1992.

(%)

1992	Coa/tot	Cnfgas/tot	Ele/tot	Tpr/tot	Coke/tot
11	0.965782	0.006358	0.005697	0.02212	4.35E-05



From here we can conclude primarily that there are serious problems exiting in the efficiency of Chinese energy production and the structure of power generation, which are the serious waste of coal resources result from the lowest ratio of coal re-exploitation (it's only 32.6% lower than the average lever all over the world [2]) and the proportion of coal-power over all of the power generation is too big (over 90%) results in the Power generation(includes the steam and hot water production and supply) sector is the first sector of SO2 and CO2 emission in China.

4. Basic Scenario Analysis

4.1 Basic I-O Model

According to the basic relationship of table1 (row and column), the following tow kinds of Input-output models are the basis of our all analysis.

1) Physical Models

$$G^e \underline{\alpha} X^e + G^{p1} X^{p1} + G^{p2} X^{p2} + G^{p3} X^{p3} + G^w \underline{\beta} X^w + Y^e = X^e$$

$$A^{e1} \underline{\alpha} X^{e1} + A^{p11} X^{p1} + A^{p12} X^{p2} + A^{p13} X^{p3} + A^{w1} \underline{\beta} X^{w1} + Y^{p1} = X^{p1}$$

$$A^{e2} \underline{\alpha} X^{e2} + A^{p21} X^{p1} + A^{p22} X^{p2} + A^{p23} X^{p3} + A^{w2} \underline{\beta} X^{w2} + Y^{p2} = X^{p2}$$

$$A^{e3} \underline{\alpha} X^{e3} + A^{p31} X^{p1} + A^{p32} X^{p2} + A^{p33} X^{p3} + A^{w3} \underline{\beta} X^{w3} + Y^{p3} = X^{p3}$$

$$F^e \underline{\alpha} X^e + F^{p1} X^{p1} + F^{p2} X^{p2} + F^{p3} X^{p3} + F^w \underline{\beta} X^w + Y^w = X^w$$

where, $G^* = (g^*_{ij})^T$, $A^* = (a^*_{ij})^T$, $F^* = (f^*_{ij})^T$, $X^e = \underline{\alpha}^{-1} Z^e$, $X^w = \underline{\beta}^{-1} Z^w$, $Z^p = X^p$, $Z^* = (Z^*_1, Z^*_2, \ldots, Z^*_k)^T$, $Y^* = (Y^*_1, Y^*_2, \ldots, Y^*_k)^T$, $X^* = (X^*_1, X^*_2, \ldots, X^*_k)^T$ (for * as e, p**(**= primary energy products, second energy products, and the others products), w, k = L, N, M, and " T" indicates transferred matrix), $\underline{\alpha} = \mathrm{diag}(\alpha_1, \alpha_2, \ldots, \alpha_L)$, $\underline{\beta} = \mathrm{diag}(\beta_1, \beta_2, \ldots, \beta_N)$, $g^e_{ij} = U^e_{ij} / Z^e_j$, $g^p_{ij} = U^p_{ij} / Z^p_j$, $g^w_{ij} = U^w_{ij} / Z^w_j$, $a^e_{ij} = q^e_{ij} / Z^e_j$, $a^p_{ij} = q^p_{ij} / Z^p_j$, $a^w_{ij} = q^w_{ij} / Z^w_j$, $f^e_{ij} = e^e_{ij} / Z^e_j$, $f^p_{ij} = e^p_{ij} / Z^p_j$, $f^w_{ij} = e^w_{ij} / Z^w_j$, $\alpha_i = Z^e_i / X^e_i$, $\beta_i = Z^w_i / X^w_i$.

2) Value Models

$$P^e = G^e P^e + A^{e1} P^{p1} + A^{e2} P^{p2} + A^{e3} P^{p3} + F^e P^w + B^e$$

$$P^{p1} = G^{p1} P^e + A^{p11} P^{p1} + A^{p12} P^{p2} + A^{p13} P^{p3} + F^{p1} P^w + B^{p1}$$

$$P^{p2} = G^{p2} P^e + A^{p21} P^{p1} + A^{p22} P^{p2} + A^{p23} P^{p3} + F^{p2} P^w + B^{p2}$$

$$P^{p3} = G^{p3} P^e + A^{p31} P^{p1} + A^{p32} P^{p2} + A^{p33} P^{p3} + F^{p3} P^w + B^{p3}$$

$$P^w = G^w P^e + A^{w1} P^{p1} + A^{w2} P^{p3} + A^{w3} P^{p3} + F^w P^w + B^w$$

where $P^* = (p^*_1, p^*_2, \ldots, p^*_k)^T$, $B^* = (b^*_1, b^*_2, \ldots, b^*_k)^T$(for * as e, p**(**= primary energy products second energy products, and the others products), w, and k = L, N, M), $b^e_j = N^e_j / Z^e_j$, $b^p_j = N^p_j / Z^p_j = N^p_j / X^p_j$, $b^w_j = N^w_j / Z^w_j$, P^e_i be the resource tax imposed on for using per unit resource i (here refers to the recovering cost of per unit resource i); P^p_i be the price of product i; P^w_i be the emissive cost imposed on for emitting pollutant i (here refers to the cost consumed by managing per unit pollutant i).

4.2 Forecast for GDP and Final Demand

According to Chinese Outline of the 9th Five Year Plan for the National Economic and Social Development and the Lon-Term Targets Till the Year 2015, which adopted by Chinese National People's Congress in March 1996, we forecast Chinese GDP based on the annual GDP growth rate be 8% before 2000, and 7% from 2001 to 2020 and 1992 be the base year as following,

$$GDP_t = GDP_{1992}(1 + r_{GDP})^t \quad t=0,1,2,\ldots\ldots\ldots$$

where, r_{GDP} is the annual GDP growth rate.

And we forecast final demand (FD) of non-energy sectors under the assumption of the final demand structure of non-energy sectors are unchangeable from 1992 to 2020.

$$FD_t^{(*)} = \alpha_{(*)} * GDP_t$$

where, $\alpha_{(*)}$ is the proportion of each non-energy sector final demand against the GDP on 1992, (*) = Farming forestry animal husbandry fishery and water conservancy, Food beverage and tobacco, Textiles, Paper-making and paper products, Chemicals and allied products, Building materials and other, Smelting and pressing of metals, Machine building electric and electronic equipment, The others manufacturing, Construction, Transportation post and telecommunications services, Commerce food services materials supply and marketing and storage, Nonmaterial (the others services) production sectors.

4.3 Forecast for Energy Final Demand

Final Demand of Energy are forecast by means of elasticity forecasting method,

$$FD_t^{(*)} = FD_{1992}^{(*)}(1 + \varepsilon_{(*)} * r_{GDP})^t \quad t=0,1,2,\ldots..$$

where, $\varepsilon_{(*)}$ are elasticity of each energy products final demand against GDP, (*)=coal, petroleum and natural gas, power, petroleum refinery products and Coke.

The elasticity of each energy products final demand is estimated based on the data from International Energy Agency (IEA) Statistics Year Book.

1) **Elasticity of Coal**

COATFCOL = 0.23271356*GDPL + 8.5485887 + [AR(1)=-0.051307486]

Elasticity of Coal = 0.23271356

(Note: though the Adjusted R-squared in our above estimated is small, we adopt it's results by comparing with the others estimated results and Chinese real situation)

2) **Elasticity of Petroleum and Natural Gas**

PETROGASTFCOL = 1.4155902*GDPL - 10.608795 + [AR(1)=0.38531649]

Elasticity of Petroleum and Natural Gas = 1.4155902

(Note: this elasticity is actually the elasticity of natural gas against GDP since the final demand of petroleum is zero in 1992)

3) Elasticity of Electricity

ELETFCOL = 1.068432*GDPL - 4.4455671 + [AR(1)=0.093879952]

4) Elasticity of Petroleum Refinery Products

TPRTFCOL = 0.63327857*GDPL + 1.6259491 + [AR(1)=0.25973122]

5) Elasticity of Coke

Lacking of the relevant data, we assume the elasticity of coke final demand against GDP is as same as the elasticity of coal.

Elasticity of Coke = 0.23271356

4.4 Forecast for Total Energy Consumption

We assume further that both Chinese basic structure of technological economic relationship (direct consumption coefficient matrix) and the elasticity of each energy products final demand (i.e. 0.23(coal), 1.42(petroleum and natural gas), 1.07(electricity), 0.63(petroleum refinery products), 0.23(coke)) keep unchanging from 1992 to 2020 . Then in light of the above Final Demand (non-energy & energy) Forecasting and the Complete Consumption Coefficient (Appendix Complete Consumption Coefficient Table), we can forecast total energy consumption as follows,

$$\begin{pmatrix} X_t^N \\ X_t^{FN} \end{pmatrix} = (I - A)^{-1} \begin{pmatrix} Y_t^N \\ Y_t^{FN} \end{pmatrix}$$

where A is the direct consumption coefficient matrix (92), X_t^N, Y_t^N are total consumption and final demand of energy products in year t respectively, X_t^{FN}, Y_t^{FN} are total consumption and final demand of non-energy products in year t respectively, t=1993,1994,……,2020.

4.5 Forecast for Natural Resources Used

As to the forecast and analysis of natural resources used directly, here only coal resources be considered . On the other hand, we assume the coal re-exploitation rate of China keeps 32.6% [2] unchanging from 1992 to 2020, as another assumption of the basic scenario. Hence, the forecast of coal resource used directly can be get as follows,

$$D_t = S_t / \sigma$$

$$S_t = (1 + \lambda * r_{GDP})^t S_0$$

where D_t, S_t are the amount of coal resource used and of coal product produced respectively, σ is recovery ratio of coal, λ is the production elasticity of coal (here λ = 0.32 [5] , S_0 is the total coal production of China in base year (1992).

4.6 Forecast for SO2,CO2 Emission

To estimate Chinese SO2 and CO2 emission in the Future (1998-2020), we only considered the emission of SO2 from coal burning and CO2 emission from primary energy (coal, petroleum and natural gas) used here.

Considering 84% coal are used as directly burning and the average sulphur content of coal is 0.0205712 in China today, so we calculated the SO2 emission as follows,

The amount of SO2 emission (in ton) =1.6*0.0205712*0.84*Total coal Consumption (in ton)

The amount of CO2 emission (in ton) = The amount of CO2 emission with coal used +

The amount of CO2 emission with petroleum and natural gas used =0.651*Total coal Consumption (in tons of coal equivalent, TCE)+((0.543+0.404)/2)* total petroleum & natural gas Consumption (in tons of coal equivalent, TCE)

where parameters 0.651, 0.543 and 0.404 are total CO2 emission per unit coal, petroleum and natural gas consumption (ton/TCE), respectively [5] .

4.7 Conclusion

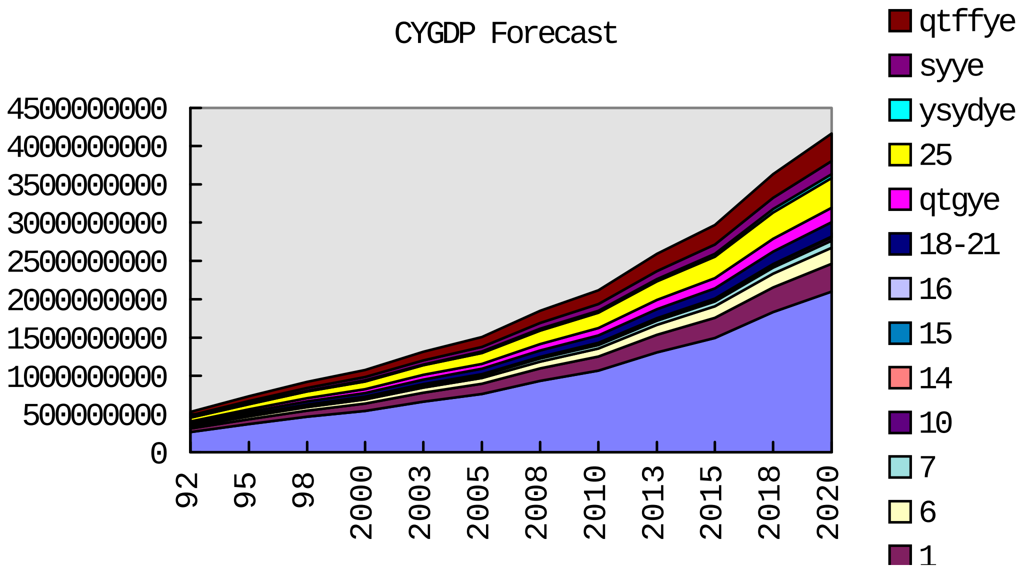
According to Chinese government target in the 9th Five Year Plan for the National Economic and Social Development and the Lon-Term Targets Till the Year 2015—the annual GDP growth rate will be 8% before 2000, 7% from 2001 to 2020, and our four assumptions—Chinese basic structure of technological economic relationship (direct consumption coefficient matrix) keeps unchanging from 1992 to 2020; the final demand structure of non-energy sectors keeps 1992's structure unchangeable; the elasticity of energy final demand against GDP are keep 0.23271356 (coal), 1.4155902 (natural gas), 1.068432 (power), 0.63327857 (petroleum refinery products), 0.23271356 (coke) from 1992 to 2020; and the coal re-exploitation rate of China keeps 32.6% [2] unchanging from 1992 to 2020, then we have the following conclusions about Chinese energy-economy-environmental before 2020.

1) The GDP will be about 2.1×10^{14} RMB in 2020, and final demand of each the non-energy sectors (Farming forestry animal husbandry fishery and water conservancy, Food beverage and tobacco, Textiles, Paper-making and paper products, Chemicals and allied products, Building materials and other, Smelting and pressing of metals, Machine building electric and electronic equipment, The others manufacturing, Construction, Transportation post and telecommunications services, Commerce food services materials supply and marketing and storage, Nonmaterial (the others services) production sectors) will be 3.67×10^{13} , 2.07×10^{13}, 9.05×10^{12}, 4.51×10^{12}, 3.08×10^{12}, 1.97×10^{12}, 4.1×10^{12}, 1.87×10^{13}, 1.88×10^{13}, 3.91×10^{13}, 5.22×10^{12}, 1.69×10^{13}, 3.57×10^{13} RMB , respectively.

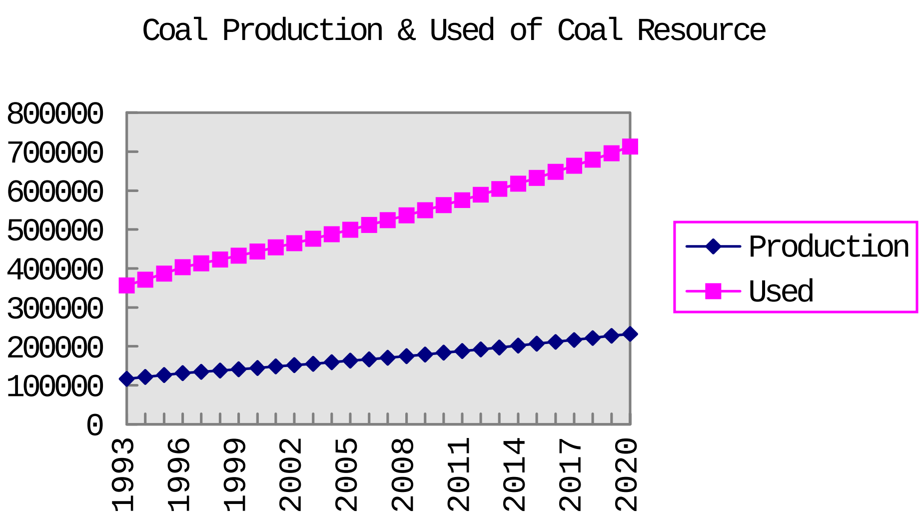
(10000 RBM)

	92	95	98	2000	2003	2005
GDP	2.66E+08	3.69E+08	4.65E+08	5.42E+08	6.64E+08	7.6E+08
1	46685129	64629195	81414175	94961489	1.16E+08	1.33E+08
6	26321907	36439091	45902762	53540978	65590005	75094008
7	11496842	15915810	20049338	23385546	28648301	32799445
10	5730701	7933374	9993767	11656729	14279995	16349169
14	3907692	5409667	6814622	7948575	9737347	11148290
15	2506609	3470058	4371274	5098654	6246071	7151128
16	526619	729033	918372	1.1E+07	1.3E+07	1.5E+07

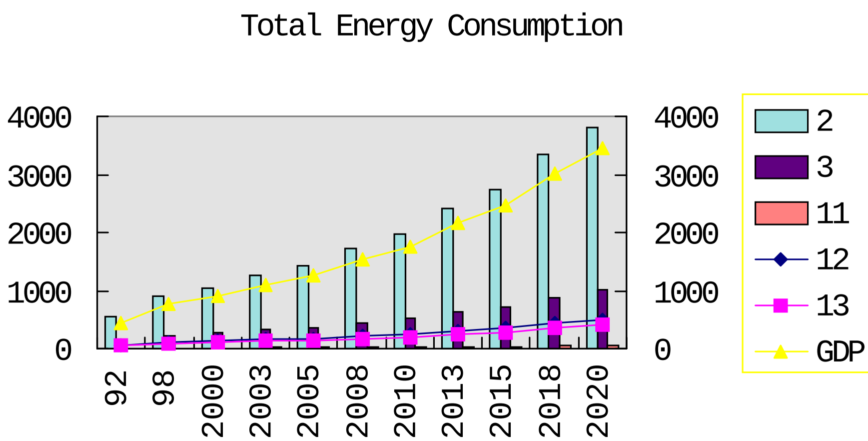
	8	3	0			
18-21	23800199	32948130	41505156	48411612	59306310	67899804
qtgye	23916473	33109096	41707926	48648123	59596046	68231523
25	49697119	68798884	86666783	1.01E+08	1.24E+08	1.42E+08
ysydye	6629727	9177953	11561578	13485424	16520225	18914008
syye	21480318	29736571	37459517	43692778	53525535	61281394
qtffye	45332593	62756793	79055488	92210317	1.13E+08	1.29E+08
	2008	2010	2013	2015	2018	2020
GDP	9.31E+08	1.07E+09	1.31E+09	1.5E+09	1.83E+09	2.1E+09
1	1.63E+08	1.87E+08	2.29E+08	2.62E+08	3.21E+08	3.67E+08
6	91993390	1.05E+08	1.29E+08	1.48E+08	1.81E+08	2.07E+08
7	40180731	46002915	56355534	64521453	79041573	90494674
10	20028435	22930553	28090906	32161280	39398960	45107858
14	13657135	15636052	19154831	21930367	26865649	30758474
15	8760439	10029826	12286964	14067346	17233108	19730180
16	1.8E+07	2.1E+07	2.6E+07	3E+07	3.6E+07	4.1E+07
18-21	83180181	95232980	1.17E+08	1.34E+08	1.64E+08	1.87E+08
qtgye	83586551	95698234	1.17E+08	1.34E+08	1.64E+08	1.88E+08
25	1.74E+08	1.99E+08	2.44E+08	2.79E+08	3.42E+08	3.91E+08
ysydye	23170474	26527873	32497777	37206706	45579825	52184329
syye	75072344	85950319	1.05E+08	1.21E+08	1.48E+08	1.69E+08
qtffye	1.58E+08	1.81E+08	2.22E+08	2.54E+08	3.12E+08	3.57E+08

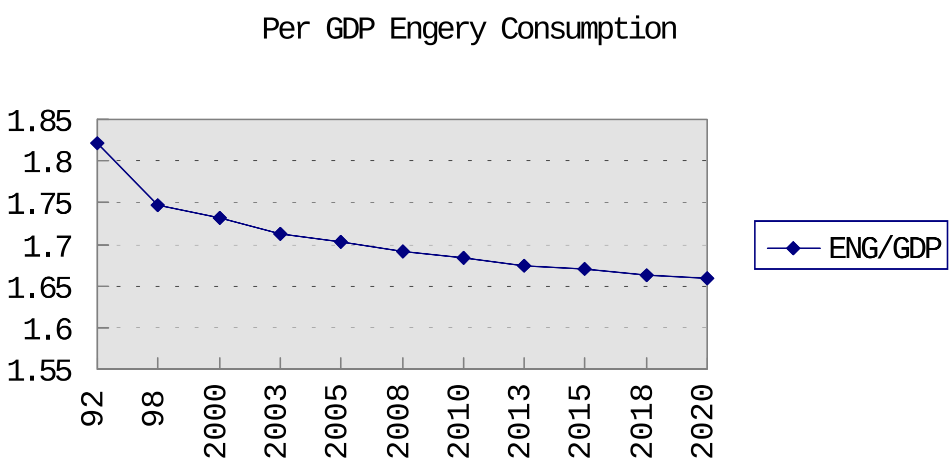


2) In 2020, gross production of coal in China is about 2323.52 million ton but the total used of coal resource in the production process will be about 7122.4 million ton



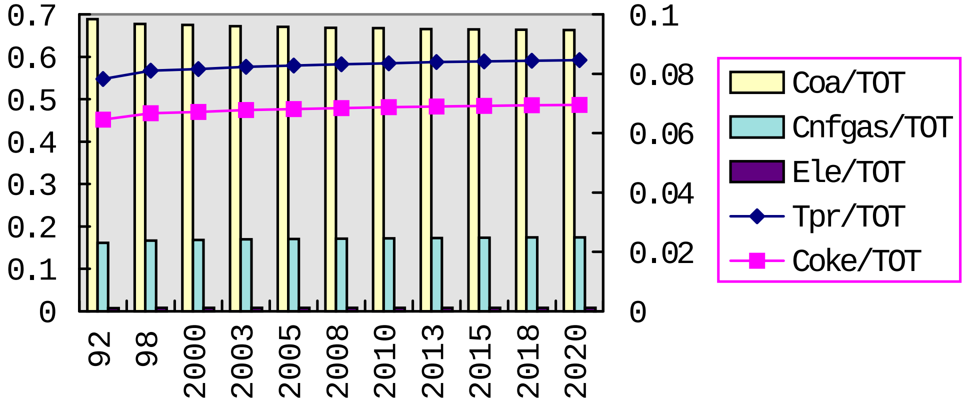
3) Till 2020, total energy consumption will be 9209.566 million TOE, in which coal will be million TOE, petroleum & natural gas will be 1002.565 million TOE, power will be 47.8574 million TOE, petroleum refinery products will be 486.2151 million TOE, coke will be 399.419 million TOE, however total energy consumption per GNP will decrease to about 1.64 (TOE/1000000US$) in 2020 from 1.83 (TOE/1000000US$) of 1992.





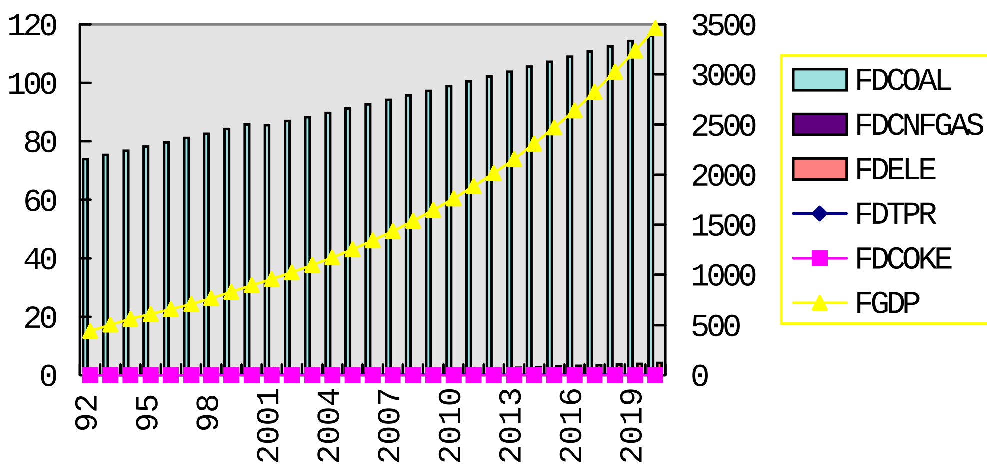
4) The structure of total energy consumption are changed with the proportion of coal against total energy consumption is changed from 1992's 0.688403 to 2020's 0.663072, power's changes from 0.007696 to 0.008329, petroleum refinery products' from 0.07829 to 0.084615.

Structure of Total Energy Consumption



5) The structure of energy final consumption are also changed, in which the proportion of coal against total energy final consumption is changed greatly from 1992's 965027 to

Energy Final Demand

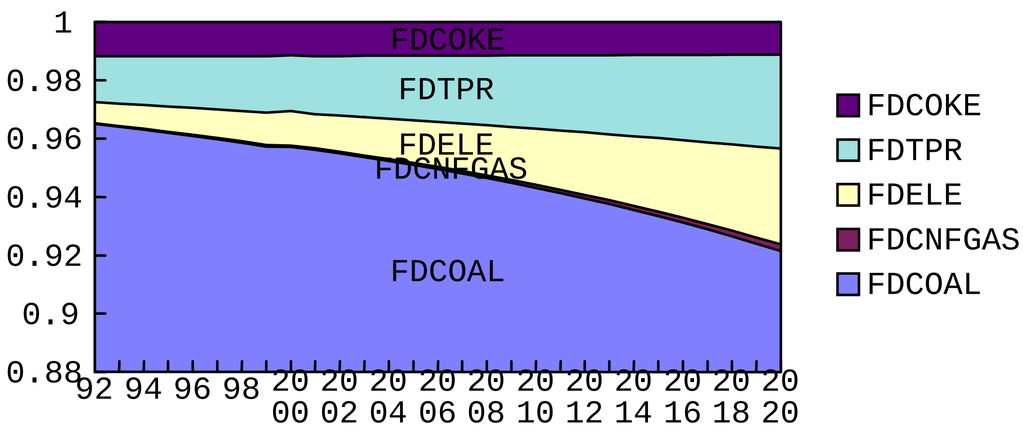


2020's 0.921428, power's changes from 0.007696 to 0.008329, natural gas and petroleum refinery products' change greatly too, from 0.000261 to 0.002237, 0.015733 to 0.032188, respectively

Structure of Energy Final Consumption (%)

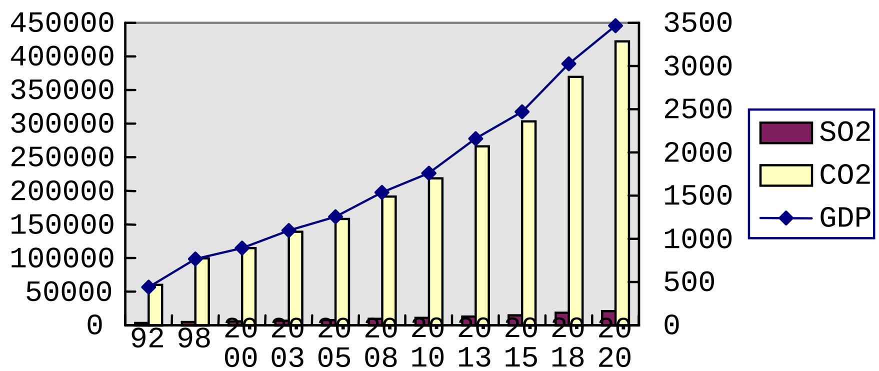
	92	93	94	95	96	97
FDCOAL%	0.965027	0.964072	0.963071	0.962024	0.960926	0.959776
FDCNGAS%	0.000261	0.000285	0.000312	0.00034	0.000371	0.000405
FDELE%	0.007187	0.007651	0.008145	0.00867	0.009229	0.009823
FDTPR%	0.015733	0.016212	0.016705	0.017211	0.017733	0.018268
FDCOKE%	0.011791	0.01178	0.011767	0.011755	0.011741	0.011727
	98	99	2000	2001	2002	2003
FDCOAL%	0.958571	0.957308	0.957089	0.956096	0.954883	0.953618
FDCNGAS%	0.000442	0.000483	0.000528	0.000524	0.000566	0.000611
FDELE%	0.010454	0.011126	0.011853	0.011784	0.012446	0.013145
FDTPR%	0.01882	0.019386	0.019047	0.019914	0.020437	0.020973
FDCOKE%	0.011712	0.011697	0.011482	0.011682	0.011667	0.011652
	2004	2005	2006	2007	2008	2009
FDCOAL%	0.952299	0.950924	0.949489	0.947992	0.94643	0.944801
FDCNGAS%	0.00066	0.000713	0.00077	0.000831	0.000898	0.000969
FDELE%	0.013882	0.01466	0.015481	0.016346	0.017259	0.018221
FDTPR%	0.021522	0.022084	0.022659	0.023247	0.023849	0.024465
FDCOKE%	0.011636	0.011619	0.011601	0.011583	0.011564	0.011544
	2010	2011	2012	2013	2014	2015
FDCOAL%	0.943101	0.941326	0.939475	0.937542	0.935525	0.93342
FDCNGAS%	0.001046	0.001129	0.001219	0.001315	0.001419	0.001532
FDELE%	0.019235	0.020304	0.02143	0.022617	0.023868	0.025185
FDTPR%	0.025095	0.025739	0.026397	0.02707	0.027757	0.028458
FDCOKE%	0.011523	0.011502	0.011479	0.011456	0.011431	0.011405
	2016	2017	2018	2019	2020	
FDCOAL%	0.931223	0.928929	0.926535	0.924036	0.921428	
FDCNGAS%	0.001653	0.001783	0.001923	0.002074	0.002237	
FDELE%	0.026572	0.028032	0.029569	0.031187	0.032889	
FDTPR%	0.029175	0.029906	0.030651	0.031412	0.032188	
FDCOKE%	0.011378	0.01135	0.011321	0.01129	0.011259	

Structure of Energy Final Consumption



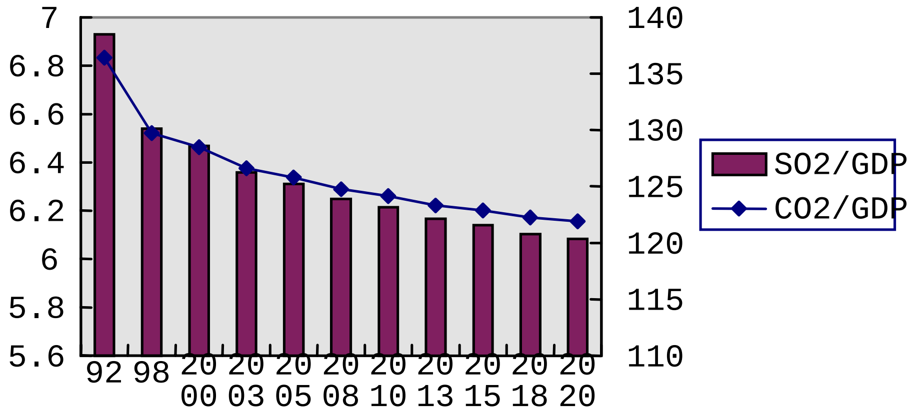
6) Total SO2 and CO2 emission will be 210.68 million tons, 422.172 million tons, respectively in 2020,

Total SO2-CO2 Emission



however per GDP SO2 and CO2 emission will be decrease from 1992's 6.93 (tons/100000US$) and 136.4 (tons/100000US$) to 2020's 6.08(tons/100000US$) and 121.9 (tons/100000US$).

Per GDP SO2-CO2 Emission



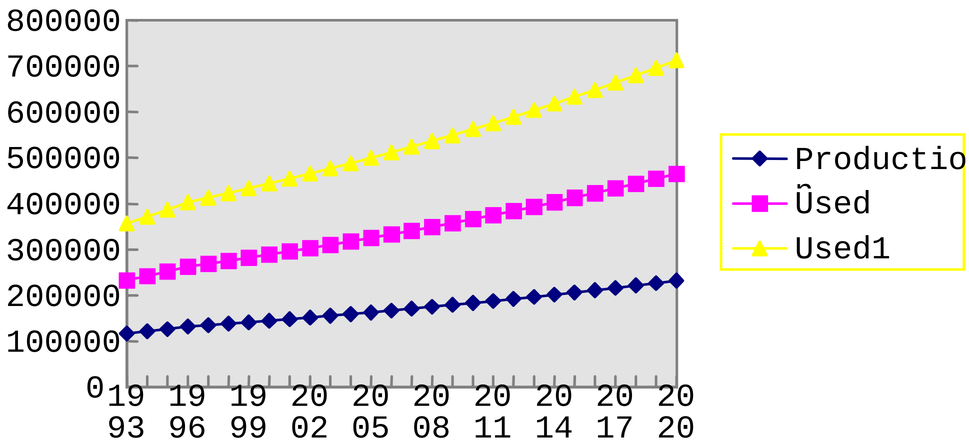
5. Others Scenarios Analysis

Based on the above Basic Scenario Analysis, we also estimated Chinese Energy-Economy-Environmental situation in the future, under the four others' Scenario assumed.

5.1 Scenario I

For this Scenario, all assumptions are also just same as that of Basic Scenario excepts the coal re-exploitation rate of China is changed, which the coal re-exploitation rate of China increase to 50% from 1992's 32.6% in 2020, by considering Chinese Coal Law was promulgated in 1996 and there are over half of the villages and towns' coal mines will realize semi-mechanization and scale operation Hydropower of China and Nuclear Power will be increase greatly which Chinese Three Gorge Dam will be build up in 2009 and new Nuclear Power Generation Station will be build up in the next

Coal Production & Coal Resource Used



century.

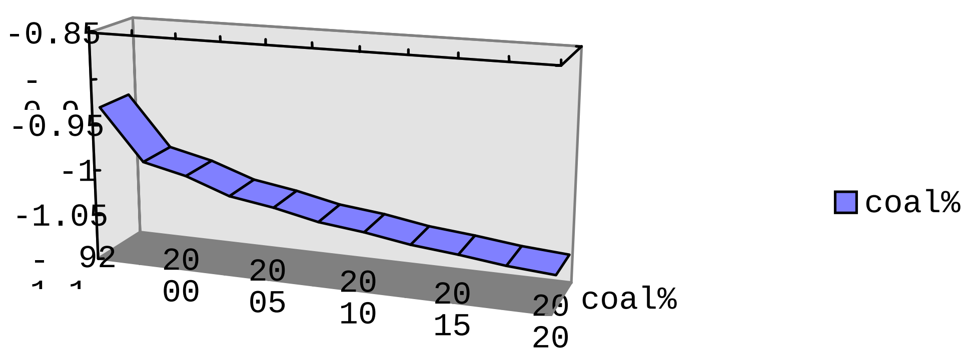
5.2 Scenario II

In this Scenario, all assumptions are just same as that of Basic Scenario excepts the final demand structure of non-energy sectors are difference between 1992's, that is, the proportion of final demand for Chemicals and Allied Products against GDP will decrease 1% from 1992's, and the proportion of final demand for Nonmaterial Production Sectors against GDP will increase 1% from 1992's in 2020.

Comparing with the relevant results of Basic Scenario, we have the following results,

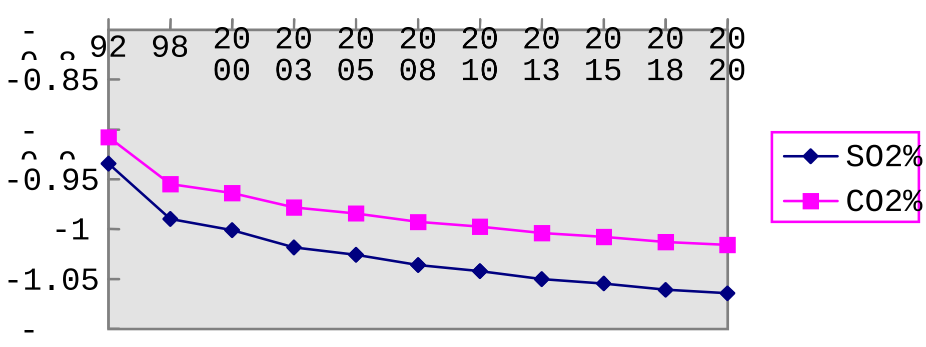
Conclusion: Under the assumption that the proportion of final demand for Chemicals and Allied products against GDP will decrease 1% from 1992's, and the proportion of final demand for Nonmaterial Production Sectors against GDP will increase 1% from 1992's in the future, total coal consumption of China will be decrease 1.0644% in 2020, and SO2, CO2 emission will decrease 1.0644% ,

Total Coal Consumption Changed with Final Demand Structure Changed



and 1.016% in 2020,respectively, comparing with the Basic Scenario's keeping the 1992's final demand structure of non-energy sectors unchangeable in 2020.

SO2-CO2 Emission Changed with Final Demand Structure Changed



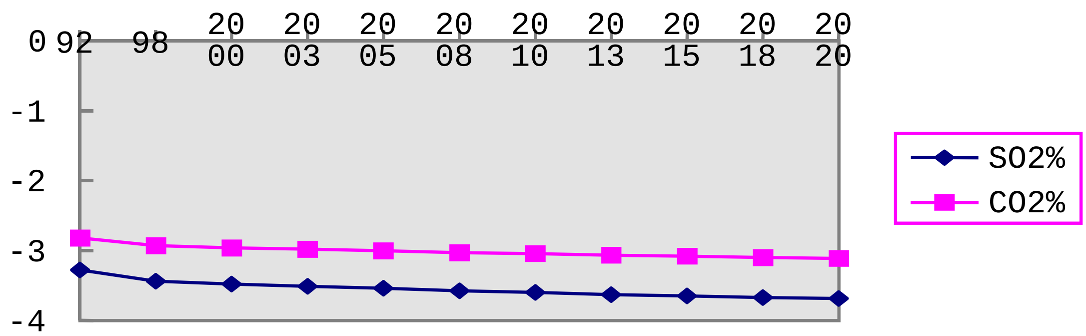
5.3 Scenario III

For this Scenario, all assumptions are also just same as that of Basic Scenario excepts the energy consumption structure in Power Generation is changed, which the proportion of coal consumption against total energy consumption in Power Generation decrease to 86.58% from 1992's 96.58% , by considering Chinese Hydropower of China and Nuclear Power will be increase greatly which Chinese Three Gorge Dam will be build up in 2009 and new Nuclear Power Generation Station will be build up in the next century.

Comparing with the relevant results of Basic Scenario, we have the following results,

Conclusion: Under the assumption that the energy consumption structure in Power Generation is changed, which the proportion of coal consumption against total energy consumption in Power Generation decrease to 86.58% from 1992's 96.58%, SO2, CO2 emission will decrease 3.6878% and 3.1096% in 2020, respectively, comparing with the Basic Scenario's keeping the 1992's energy consumption structure in Power Generation unchangeable in 2020.

SO2-CO2 Emission Changed with Coal Consumption Changed in Power Generation

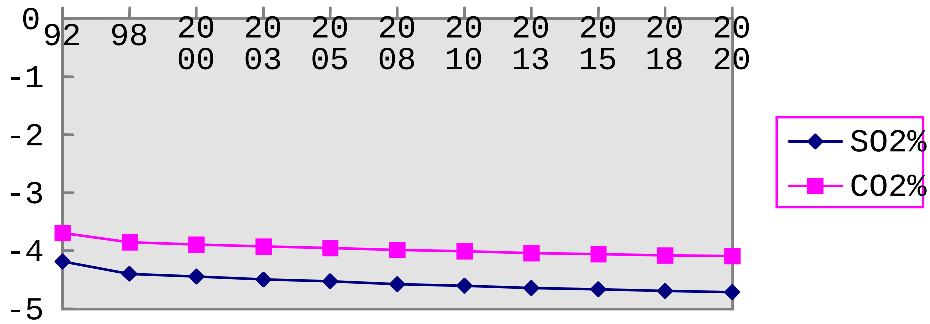


5.4 Scenario IV

In this Scenario, the assumptions is just an comprehensive assumption of Scenario I and Scenario II, that is the final demand structure of non-energy sectors are difference between 1992's, that is, the proportion of final demand for Chemicals and Allied products against GDP will decrease 1% from 1992's, the proportion of final demand for Nonmaterial Production Sectors against GDP will increase 1% from 1992's in the future, and the energy consumption structure in Power Generation is also changed, which the proportion of coal consumption against total energy consumption in Power Generation decrease to 86.58% from 1992's 96.58% , and the others assumption is just the same as Basic Scenario.

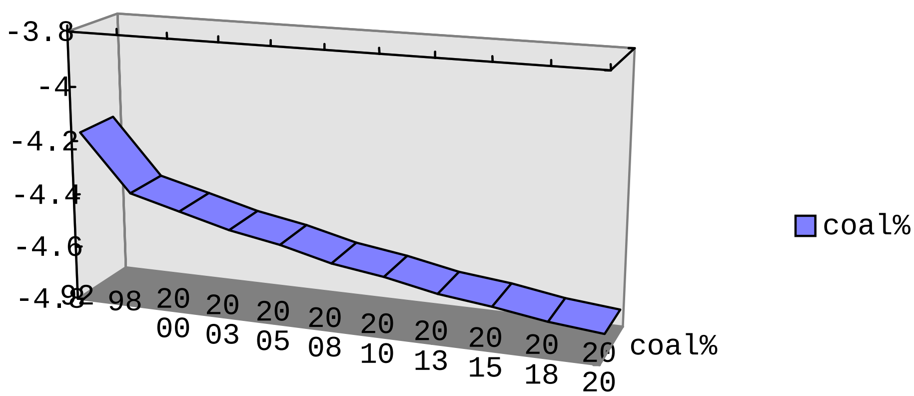
Comparing with the relevant results of Basic Scenario, we have the following results,

Conclusion: Under the assumption that the final demand structure of non-energy sectors are difference between 1992's, that is, the proportion of final demand for Chemicals and Allied products against GDP will decrease 1% from 1992's, and the proportion of final demand for Nonmaterial Production Sectors against GDP will increase 1% from 1992's in the future, and the energy consumption structure in Power Generation is also changed, which the proportion of coal consumption against total energy consumption in Power Generation decrease to 86.58% from 1992's 96.58%, total coal consumption of China will be decrease 4.714% in 2020, SO2-CO2 Emission Changed



and SO2, CO2 emission will decrease 4.714% and 4.09% in 2020,respectively, comparing with the Basic Scenario's keeping the 1992's final demand structure of non-energy sectors unchangeable and the 1992's energy consumption structure in Power Generation unchangeable in 2020.

Total Coal Consumption Changed



6. Conclusion and Suggestion

From the above analysis, we have the following general conclusions and suggestions about Chinese current and future's energy-resources-economy-environmental situation,

1 The low coal re-exploitation rate in China is one key factor which results in the low efficiency and high waste in Chinese current subsoil energy resources e.p. coal exploitation process.

2 It's the necessary way to protect Chinese natural resources by promoting the re-exploitation rate of subsoil energy resources e.p. coal and reducing the waste in the resources exploitation process.

3 Coal used, especially, coal used in power generation is main cause of SO2 and CO2 emitted in today's and future's China.

4 Change the energy consumption structure in power generation, by means of raise the efficiency of energy transformation, increasing hydropower and nuclear power and decreasing firepower, is an effective way to reduce SO2 and CO2 emission.

5 Changing the final demand structure, by decreasing the proportion of Chemicals and allied products and increasing the proportion of the third industrial products and services in final demands, is also an effective way to reduce SO2 and CO2 emission.

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