ANALYSIS OF ENERGY CONSUMPTION AND ACCOMPANYING EMISSIONS CHANGE IN CHINA

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In this research, first, emission of NO_x, SO_x, and CO_2 were calculated by multiplying the obtained energy consumption for each fuel type by its corresponding emission factors by sectors. And then, the Input-Output table of 1987, 1990, 1992, 1995 and 1997, was consolidated to convert a perfectly square matrix with 26 rows and 26 columns for calculation for the embodied energy consumption and emissions intensity. Using these 5 years data, the GDP was chose as the explanatory variable in the regression analysis for the prediction of embodied energy consumption and emission intensity till year of 2020. Intensities in more detail sectors (124 sectors) were calculated by averagely distribution energy consumption.

Key Words: *IO Analysis, Embodied Emission, Energy, Intensity*

1. Introduction

In input-output tables, which were originated by Wassily Leontief, exchanges of goods and services among industrial sectors are presented in matrix form[1]. Most of the actually available tables are specified in money units. Energy and resource flows among industries can be analyzed on the assumption that goods are transferred in direct proportion to their monetary value. Input-Output tables have been frequently applied to the analyses of environmental issues. Input-Output analysis is a powerful tool for tracing environment impact of final demand of goods, Because it considerate not only direct impact of the goods but also includes impacts originating from production layer of infinite order (capturing the entire economy). Considering of the similarity between I/O analysis and LCA, the Life Cycle Inventory which takes the form of a table summing up resource inputs and waste outputs is a type of "input-output table". This method has been used in Life Cycle Assessment (LCA), and various analyses have been conducted on energy consumption and CO_2 emissions[1),2)].

In China, a lot of researches have been focused on the energy consumption and accompanying emissions. Scenario analysis has been used by Liang et al. for analysis of energy requirement of 2010 and 2020, the influences of population, income and urbanization to the energy requirement and energy consumption intensity of three industries were analyzed. The result shows, the population and income have great influence to the energy requirement but have little influence to energy intensity. The technology development has great impact to energy consumption intensity.[3)] Research by Zhang has shown that the energy intensity fallen in China's industrial sector in the 1980's, the reasons are technology improvement and structural shifts away from energy-intensive industrial sub-sectors to less energy-intensive industrial ones.[4)]

"Life Cycle Thinking", aiming at evaluating not only direct environmental burdens associated with economic activity, but indirect- and/or induced burdens, is an essential viewpoint when we try to analyze the circulation of resources and wastes throughout the economy[1]. Zheng Lu have used I/O table to analyze the change in energy consumption in china[5], the result shows with the increase of total energy consumption, the embodied energy consumption intensity decreased from 1987 to 1997. In this research, we try to not only analyze the embodied energy intensity but also embodied emission intensity, furthermore, the prediction of energy and emission intensity were made till 2020.

2. Method

(1) Data

In this research, the input-output tables were consolidated several sectors to convert into a square matrix with 26 rows and 26 columns. Next, gross consumption, expressed as physical amount for each sector, was estimated for 8 types of fuels. In China, since the first SNA (System of National Accounts) Input-Output Table for 1987 was compiled, every 5 years, for 1992 and 1997 another 2 Input-Output Table were published, and there were also two extended table for 1990 and 1995 [6].

For the statistic data of energy consumption, there are Chinese Energy Statistic Book for 1986, 1989, 1991-1996, 1997-1999, and 2000-2002 [7].

Besides all above mentioned data, there was an Input-output table of Japan and China in 1987 for the analysis of energy and environment analysis, which was compiled by Institute of Economy Trade and Industry of Japan

(2) Prediction of Embodied Intensity

Input-output analysis is a top-down economic technique that use sectoral monetary transactions data to account for the complex interdependencies of industries in modern economies. Within the scope of life-cycle assessment, generalized input-output analyses result in an $f \times n$ matrix E of factor multipliers, that is, embodied consumption or emission of f production factors (such as water, energy, resource and emissions) per unit of final demand of commodities produced by n industry sectors. Matrix F is an $f \times n$ matrix containing sectoral production factor usage (such as direct energy consumption, CO_2, NO_x, SO_2 emissions factor). Matrix A is an $n \times n$ direct coefficient matrix of Input-Output table.

$$E = F\{I - A\}^{-1} \tag{1}$$

where I is the $n \times n$ unity matrix.

Using Equation (1) the embodied emission intensity in 1987, 1990, 1992, 1995 and 1997 were calculated. Considering of it's well correlativity with GDP, the GDP was chose as the explanatory variable in the regression analysis for the prediction of embodied energy consumption and emission intensity till year of 2020.

(3) Calculation of Embodied Intensity Subtracting Imported Burdens

Using the equation (1), there left one problem, since it is difficult to make an accurate estimate of environmental burdens for imported products. The following method involves calculating the environmental burden for only domestic production activities, and excludes inputs from imported products.

The import coefficients m_i that represent percentages of imported products with respect to intermediate demand and domestic final demand in sector i were expressed in diagonal Matrix M, using $(I\text{-}M)A$, the environmental burden for imported products was subtracted. Therefore the equation (2) provided embodied intensity for domestic producer goods, giving an accurate value for actual embodied burdens domestically generated.

$$E = F\{I - (I - M)A\}^{-1} \tag{2}$$

In the aforementioned input-output tables, only the I/O table of 1997 and I/O table of Japan and China in 1987 have gave import and export data separately. Therefore the embodied intensity calculated by Equation (2) was used just for calculating for the year of 1987 and 1997, and the comparison of these two years data were made.

(4) Emission factors

In the research, at the first step, the energy consumption by 8 types of fuel (coal, coke, crude oil, gasoline, diesel, kerosene, fuel oil and nature gas) was calculated by 26 sectors according with the 26 sectors of I/O table. And then by multiplying the emission factors of NO_x, CO_2 and SO_2, the direct emission amount could be calculated.

$$D_{i,j} = E_{i,j} \times Ef_{i,j} \qquad (3)$$

Where, $D_{i,j}$ indicates direct emission by consumption of fuel type i in sector j; $E_{i,j}$ indicates direct energy consumption of fuel type i in sector j. And $Ef_{i,j}$ indicates emission factor by fuel type i in sector j.

Because there weren't special emission factors of CO_2 for China, in this research, emission factor of Japan will be used for the calculation. After data collection, three emission factors have been found and shown in table 1, emission factor of Japan in Investigation Report of CO_2 Emission in 1992 and 2000, emission factor of IPCC[8]. And the emission factor of Japan in Investigation Report of CO_2 Emission of Japan in 2000 is the newest data, and is about middle value in these three emission factors, therefore it was chosen for the calculation.

The SO_2 emissions are very different according to different fuel types, sulfur content of fuel and combustion method. In the research, it is assumed from 1987 to 1997, the desulfurization equipment weren't used in China. In fact the sulfur content changes through years, but because lack of available data, from 1987 to 1997 the same sulfur content were used for calculation. Besides coal and coke, the sulfur in other fuels will 100% emitted to the atmosphere. In the iron and steel industry part of sulfur will be absorbed into the products. The final emission factors were shown in table 2. The data of sulfur content came from "Input/Output table for analysis of energy consumption & air pollution of Japan & China"[9].

EF_{NOx} (Emission factor of Nitrogen Oxides) is also changing with fuel types, form of fuels and nitrogen content. Therefore it is necessary to find suitable EF_{NOx} by fuel types and industry sectors. Because

Table 1 Emission factors of CO_2

	Average High Calorific Value (Kcal/Kg)	Kg CO_2/Gcal[a]	Kg CO_2/Gcal[b]	Kg CO_2/Gcal[c]
Raw Coal	5333	361.7	378.6	395.4
Coke	7211	427.6	450.6	452.1
Crude Oil	10691	286.6	288.1	306.5
Gasoline	11304	280.5	288.1	289.7
Kerosene	11057	283.5	286.6	298.9
Diesel	10918	286.6	289.7	309.6
Fuel Oil	10642	294.3	300.4	323.4
Natural Gas	10293	206.9	213.0	234.5
Lime stone	499.7 (kg/t Clinker)			

a: CO_2 Emission factor from Investigation Report of CO_2 Emission in 1992, Department of Earth Environment, Environmental Ministry of Japan
b: CO_2 Emission factor from Investigation Report of CO_2 Emission in 2000, Department of Earth Environment, Environmental Ministry of Japan
c: CO_2 Emission factor from Revised 1996 IPCC (Intergovernmental Panel on Climate Change) Guidelines for National Greenhouse Gas Inventories

Table 2 Emission factors of SOx

NO.	Sector	Coal	Coke	Crude oil	Resi. Oil	Gaso.	Kero.	Diesel	Nat. Gas
		Kg/t	Kg/t	Kg/t	Kg/t	Kg/t	Kg/t	Kg/t	Kg/1000Cu.m
1	**Agriculture**	14.4[a]	11.328	10	30	2.4	0.64	3.2	0.0095
11	**Electricity, Steam and Hot Water**	23.4[b]	11.328	10	30	2.4	0.64	3.2	0.0095
15	**Primary Metal Manufacturing**	18.6[c]	3.45[d]	10	30	2.4	0.64	3.2	0.0095
25	**Wholesale, Retail Trade**	14.4[a]	11.328	10	30	2.4	0.64	3.2	0.0095
26	**Severices Others**	14.4[a]	11.328	10	30	2.4	0.64	3.2	0.0095
27	**Residential**	14.4[a]	11.328	10	30	2.4	0.64	3.2	0.0095
	Other sectors	18.6[c]	11.328	10	30	2.4	0.64	3.2	0.0095

a: EF_{SOx} =12*Sulfur content
b: EF_{SOx} =19.5*Sulfur content
c: EF_{SOx} =15.5*Sulfur content
d: EF_{SOx} =(8.9/6*Sulfur content + 0.774)*2.0 ---Calculated by the total sulfur content of coke and iron ore
*** The calculation method of a, b, c, d are came from "Energy Utilization and Earth environment" Edited by National Institute of Science and Technology Policy of Japan in 1992**

Table 3 Emission factors of NO_x (Kg-NOx/10^8Kcal)

No.	Sector	Coal	Coke	Crude oil	Resi. Oil	Gaso.	Kero.	Diesel	Nat. Gas
1	Agriculture	50.0	86.3	48.4	65.7	202.4	27.4	443.1	21.8
2	Coal Mining	50.0	86.3	48.4	65.7	272.2	27.4	350.4	21.8
3	Crude Petroleum and Natural Gas	50.0	86.3	48.4	65.7	272.2	27.4	350.4	21.8
4	Metal ore mining	50.0	86.3	48.4	65.7	272.2	27.4	350.4	21.8
5	Other Mining	50.0	86.3	48.4	65.7	272.2	27.4	350.4	21.8
6	Food Manufacturing	50.0	86.3	48.4	65.7	272.2	27.4	350.4	21.8
7	Manufacture of Textiles	50.0	86.3	48.4	65.7	272.2	27.4	350.4	21.8
8	wearing & leather	50.0	86.3	48.4	65.7	272.2	27.4	350.4	21.8
9	Sawmills and Furniture	50.0	86.3	48.4	65.7	272.2	27.4	350.4	21.8
10	Paper, Cultural Articals	50.0	86.3	48.4	65.7	272.2	27.4	350.4	21.8
11	Electricity, Steam and Hot Water	147.2	86.3	58.7	79.6	272.2	27.4	350.4	85.5
12	Petroleum refineries, Coking	50.0	86.3	0.0	65.7	272.2	27.4	350.4	85.5
13	Chemical Industries	50.0	86.3	48.4	65.7	272.2	27.4	350.4	21.8
14	Building Material & Non-metallic Mineral	194.1	194.1	133.3	133.3	272.2	133.3	350.4	41.1
15	Primary Metal Manufacturing	124.9	33.6	58.7	79.6	272.2	27.4	350.4	85.5
16	Metal Products	50.0	16.7	48.4	65.7	272.2	27.4	350.4	21.8
17	Machinery	50.0	16.7	48.4	65.7	272.2	27.4	350.4	21.8
18	Transport Equipment	50.0	16.7	48.4	65.7	272.2	27.4	350.4	21.8
19	Electric Machinery	50.0	16.7	48.4	65.7	272.2	27.4	350.4	21.8
20	Electronics	50.0	16.7	48.4	65.7	272.2	27.4	350.4	21.8
21	Manufacture of Instruments, Meters	50.0	16.7	48.4	65.7	272.2	27.4	350.4	21.8
22	Industries not Elsewhere Classified	50.0	16.7	48.4	65.7	272.2	27.4	350.4	21.8
23	Construction	50.0	86.3	48.4	65.7	272.2	27.4	350.4	21.8
24	Transport and communication	50.0	86.3	48.4	65.7	272.2	27.4	350.4	15.5
25	Wholesale, Retail Trade	50.0	86.3	48.4	65.7	272.2	27.4	350.4	15.5
26	Services Others	50.0	86.3	48.4	65.7	91.1	27.4	154.5	15.5
27	Residential	39.4	39.4	48.4	65.7	272.2	19.5	350.4	18.9

there weren't suitable EF_{NOx} in China, HIGASHINO H. TONOOKA Y. had collected EF_{NOx} from USA, West Europe and Japan by literature review, and set EF_{NOx} that most close to the situation of China by 8 fuel type and 32 industry sectors[10]. In the research these EF_{NOx} was used for the calculation and shown in Table 3.

3. Results

(1) Emission intensity

With rapid economic development in China, the energy consumption and emissions from combustion of bio-fuel increased through years. The Fig.1 shows the changes of energy consumption and emissions from 1987 to 2002. The energy consumption and emission reached a peak value in 1996 and increased again after 3 years decreasing and reach a new highest value in year of 2002, in this year, 968 million toe (Ton oil equivalent = 1.0 × 10^7 kcal) of energy were consumed, 3693.5 million tons of CO_2, 26.76 million tons of SO_x and 12.01 million tons of NO_x were emitted, respectively.

In such a situation, with the increasing of total energy consumption and emission, how will the

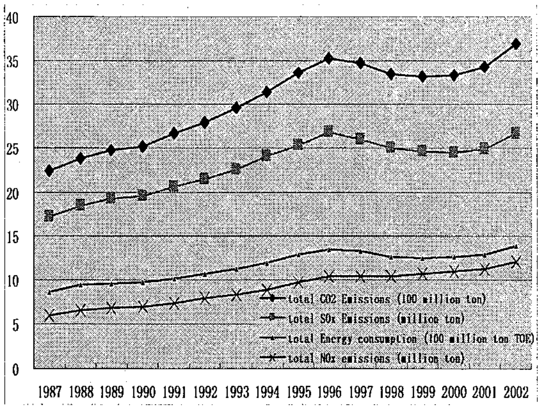


Fig.1 Emissions and Energy consumption changes

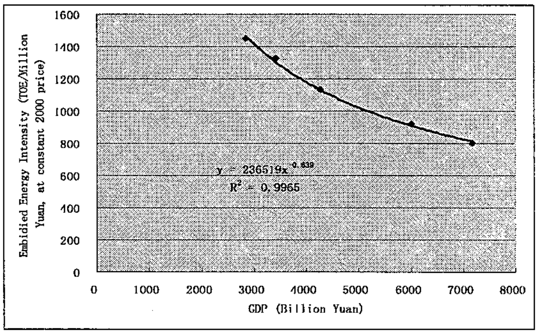


Fig.2 Energy consumption changes in 'Electric power' sector

energy and emissions intensities of final consumption changed? By using Equation (1) the embodied intensity in the year of 1987, 1990, 1992, 1995 and 1997 were calculated. Take the energy consumption in the highest intensity sector 'Electric power, steam and hot water supply' as example, the result show in Fig.2, the energy consumption intensity decreased with the increasing of GDP, and have good correlativity. Under the assumption that the GDP of China will increase by 7.5% till 2010, and by 7% from 2010 to 2020, the GDP was used in the regression analysis for the prediction of embodied energy consumption and CO_2 emission intensity till year of 2020 (Because the SO_2 and NO_x emission intensity have great correlativity with the desulfurization and denitrogen equipment, the prediction was not made for these two emissions). The correlativity, calculated intensity for the year of 1987, 1990, 1992, 1995 and 1997, predicted intensity for the year of 2000, 2010 and 2020, as well as intensity of Japan in year of 2000 (which

Table 4 Energy consumption intensity changes and prediction

Energy consumption intensity TOE/Million Yuan, at constant 2000 price										
Sector	R^2	Calculated Value					Predicted Value			Japan Data 2000
		1987	1990	1992	1995	1997	2000	2010	2020	
1	0.95	79	73	73	64	62	58	48	40	12
2	0.96	696	621	579	449	359	328	197	124	16
3	1.00	251	239	220	195	183	170	131	103	-
4	0.95	308	283	278	208	191	172	116	81	-
5	0.95	376	255	242	167	151	119	60	32	-
6	0.80	121	116	125	92	83	79	57	43	10
7	0.73	160	153	159	135	98	101	72	53	12
8	0.71	128	131	134	109	78	81	56	40	-
9	0.99	319	285	231	149	119	97	43	21	-
10	0.97	213	211	187	153	142	129	91	66	25
11	0.997	1447	1326	1133	921	802	706	438	284	121
12	0.98	448	419	399	362	356	332	275	232	28
13	0.98	361	349	287	244	217	193	126	86	26
14	0.97	519	453	378	326	253	227	132	81	28
15	0.82	771	595	466	389	430	327	201	129	71
16	0.88	405	321	298	227	247	200	132	91	21
17	0.98	310	285	234	187	180	151	94	62	13
18	0.90	278	275	198	170	170	139	88	59	14
19	0.92	303	294	237	194	202	169	115	81	-
20	0.88	187	201	163	120	124	105	68	46	10
21	0.81	199	229	166	141	139	121	83	59	9
22	0.80	291	274	219	208	112	114	59	33	13
23	0.96	330	295	220	181	170	138	79	47	11
24	0.91	264	209	194	170	163	142	99	72	29
25	0.87	119	127	108	74	77	65	41	27	-
26	0.87	135	125	131	105	95	91	69	54	-
GDP (Billion Yuan) at constant 2000 price		2841	3417	4261	6017	7175	8947	18888	37155	

Table 5 CO_2 emission intensity changes & prediction

CO_2 emission intensity (t-CO_2/Million Yuan, at constant 2000 price)										
Sector	R^2	Calculated Value					Predicted Value			Japan Data 2000
		1987	1990	1992	1995	1997	2000	2010	2020	
1	0.67	251	264	266	229	217	214	186	164	33
2	0.94	2636	2425	2264	1762	1374	1278	773	491	43
3	0.71	710	773	730	656	592	590	498	428	-
4	0.84	1033	1055	1052	770	692	650	454	329	-
5	0.97	1318	950	907	626	528	433	217	116	-
6	0.59	403	436	469	340	305	301	231	181	28
7	0.52	521	575	594	498	360	388	294	228	32
8	0.40	392	487	494	397	284	312	237	185	-
9	0.95	1028	1044	839	528	423	354	163	81	-
10	0.85	711	779	693	561	525	490	364	277	55
11	0.99	5550	5184	4440	3611	3115	2769	1732	1132	279
12	0.72	767	806	803	681	652	636	541	467	70
13	0.92	1227	1300	1080	908	799	734	502	356	69
14	0.94	2243	2100	1845	1640	1275	1209	794	543	149
15	0.89	1969	1777	1412	1148	1243	999	655	447	266
16	0.91	1179	1097	985	731	791	660	450	318	70
17	0.85	869	995	802	637	587	531	359	252	41
18	0.62	730	964	694	587	564	513	370	275	44
19	0.90	963	1008	809	647	664	567	390	277	-
20	0.37	498	725	595	426	451	416	322	255	28
21	0.46	567	800	593	502	481	453	348	274	26
22	0.67	875	975	791	751	390	425	240	143	34
23	0.89	1028	1133	851	699	662	575	374	254	36
24	0.97	788	685	620	510	509	439	306	221	81
25	0.74	382	469	386	258	268	231	150	102	-
26	0.60	425	453	480	373	334	333	267	218	-

was converted into per Million Yuan intensity by using exchange rate in 2000) were shown in table 4 and table 5.

The results shows the embodied intensity of China decreased year by year, and the decrease rate was quit higher, from 1987 to 1997, embodied intensity in some sector decreased 50%, for example in 2nd sector 'Coal mine', the energy intensity decreased from 696 to 328 TOE/Million Yuan. Embodied intensity in most sector decreased 30-50% percent from 1987 to 1997. It is very different from Japan, compare embodied energy intensity in 1990 and 2000, embodied intensity in most sectors decreased or increased within 10%. In the table 4 and table 5, it is clearly, with the predicted intensity decrease to year of 2020, the embodied intensity is still much higher than that of Japan. The energy intensities in most sectors in the year of 2020 are 4-6 times of that of Japan in 2000.

(2) Emission intensity subtracting imported burdens

Fig.3 shows sectoral direct energy consumption and contribution of each sector to the total energy consumption from the viewpoint of induced consumption by final demand. The total energy consumption (nuclear, hydro and other forms of power generation were not included) was estimated to be 929 M toe, emissions accompanied with the energy consumption was estimated 3467 Mt-CO_2/yr, 26.03 Mt-SO_2/yr and 10.4 Mt-NO_x/yr, respectively.

For direct energy consumption, the direct energy consumption of 11th sector 'Electric power, steam and hot water supply' is the highest among 26 sectors with total consumption of 270 M toe, followed by 15th sector 'Primary Metal Manufacturing' which consumed 132 M toe directly.

For energy consumption induced by final demand, the 23rd sector 'Construction' directly and indirectly induced 223 M toe, although the direct energy consumption was only 2.8 M toe. Similarly, the 26th sector 'Services Others' induced 107 M toe of energy consumption with only 9.8 M tce of directly consumption.

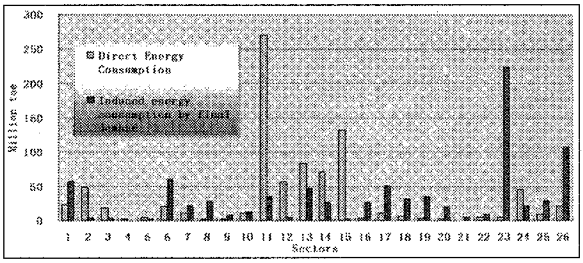
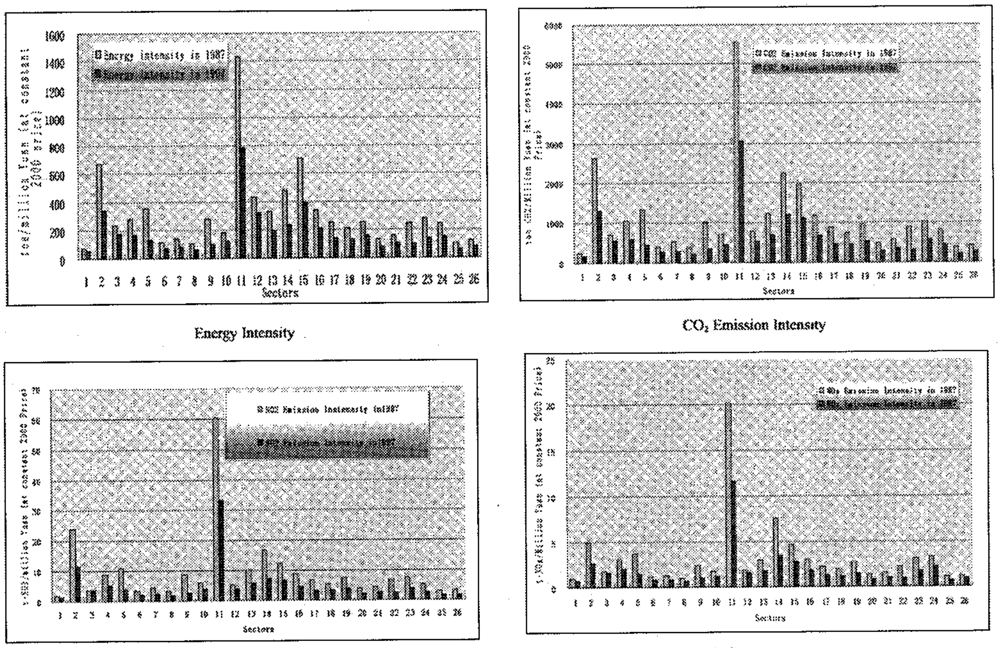


Fig.3 Direct and Induced Energy consumption in 1997

Fig.4 shows the embodied energy and emission intensity by 26 sectors in 1987 and 1997. Compare to embodied energy and emission intensity in 1987, it was clarified, the intensity in 1997 decreased in each sectors. Embodied energy and emission intensify of 11th sector 'Electric power, steam and hot water supply' is the highest with energy intensity of 1429 toe/Million Yuan and emission



Energy Intensity

CO_2 Emission Intensity

SO_2 Emission Intensity

NO_x Emission Intensity

Fig.4 Embodied Energy and Emission Intensity in 1987 and 1997

intensity of 5550 t-CO_2/Million Yuan, 60.3 t-SO_2/Million Yuan and 2.01 t-NO_x/Million Yuan in 1987, and decreased to 781.2 toe/Million-Yuan and emission intensity of 3051 t-CO_2/Million-Yuan, 33.3 t-SO_2/Million-Yuan and 11.7 t-NO_x/Million-Yuan in 1997. The second highest energy intensity is in 15th sector 'Primary Metal Manufacturing', and the second highest emission intensity is in 14th sector 'Building Material & Non-metallic Mineral Manufacturing', this is because considering of CO_2 emission from cement production and the emission factors of NO_x and SO_2 in 14th sector is higher than in 15th sector.

Furthermore, for the year of 1997, intensities in more detail sectors (124 sectors) were calculated (shown in fig.5) by averagely distribute energy consumption into sub-sectors. Because energy statistic for only part of sub-sectors could be found, energy consumption of some sub-sectors were estimated by averagely distribution of total energy according total input of I/O table by sectors. Therefore, the result can roughly reflect the difference of emission intensities when it is further divided into small sectors. For example, the 11th sector 'Electric power, steam and hot water supply' in the 26 sectors (CO_2 emission intensity is 3051 t-CO_2/ Million-Yuan) include four sub-sectors (124 sub-sectors): Production and Supply of Electric Power (CO_2 emission intensity is 3272 t-CO_2/ Million-Yuan), Steam and Hot Water (CO_2 emission intensity is 3463 t-CO_2/ Million-Yuan), Production and Supply of Coal gas (CO_2 emission intensity is 2442 t-CO_2/ Million-Yuan), and

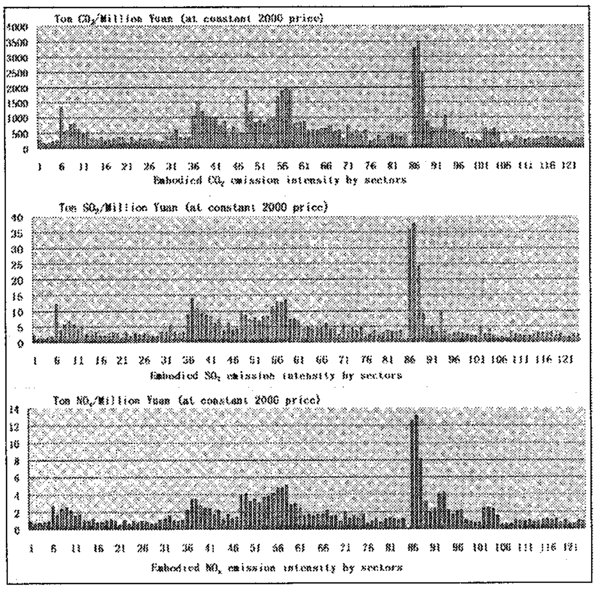


Fig. 5 Embodied Emission Intensity in 1997 by 124 sectors

Production and Supply of Tap Water(CO_2 emission intensity is 860 t-CO_2/ Million-Yuan).

4. Conclusion

In the research I/O analysis was used for the calculation of energy and emission intensity by 26 sectors for China in the year of 1987 and 1997. It was clarified, with the increase of total energy consumption, the direct and induced energy and emission intensity decreased, and the energy and emission intensity for sector of 'Electric power, steam and hot water supply' is the highest among the 26 sectors. In 1997, for energy consumption and emissions induced by final demand the sector 'Construction' directly and indirectly induced 223 M toe of energy consumption and with the highest induced emission of 901 Mt-CO_2, 6.1 Mt-SO_2 and 2.7 Mt-NO_x.

The Energy consumption and CO_2 emission intensity was estimated till 2020. The result shows, the embodied intensities are much higher than that of Japan, and it decreased quit quickly year by year unlike that of Japan in a very steady state. It will keep on decrease, and by compare the predicted embodied intensities by sectors, most of them are 4-6 times of that of Japan in 2000.

Because the limitation of energy consumption data by sectors, the embodied emission factors were classified into a very limited 26 categories. Therefore, one category contains many different products. Hereby, input-output analysis provides only an average value. It can only provide a very rough estimate. By distribution of energy consumption into sub-sectors according to total input, the emission intensities of 124 sectors were calculated.

The next step research will consider of other emissions like emission to water, to collect data about water emissions accompanying with production activities, and finally to calculate the direct and indirect emission intensities by using I/O analysis method.

REFERENCES:

1) Nansai, K., Moriguchi, Y., Tohno, S.: Embodied Energy and Emission Intensity data for Japan Using Input-Output Tables, National Institute for Environmental Studies, 2002.

2) Bundit, L., Pawinee, S.: Embedded energy and total Greenhouse gas emissions in final consumptions within Thailand, *Renewable & Sustainable Energy Reviews*, article in press, 2005.

3) Liang Q.M., Wei Y.M. Fan Y., Norio Okada: Scenario analysis model and it's application for prediction of energy requirement and energy intensity, *Chinese Journal of Management*, Vol. 1, No. 1, pp. 62-66, 2004.

4) Zhang R.J., Wang M.X, Zheng X.H., Li J., Wang Y.S., Liu X.Y. Li Y. Wang B.ZH. Chen ZH.L., Analysis of present emission status of Carbon Dioxide in China, *Climatic and Environmental Research*, Vol.6, No. 3, pp. 321-327, 2001.

5) Zheng, L., Matsuhashi, R.: Analysis on Change in Energy Consumption in China using Input-Output Table, Proceeding of the 23rd Conference of Energy and Resource academy, pp. 53-56, June, 2004.

6) Input-output table of Japan and China in 1987 for the analysis of energy and environment analysis, Research Institute of International Trade and Industry, Ministry of International Trade and Industry, 1994.

7) China Energy Statistical Yearbook, Department of Industry and Transport Statistics, National Bureau of Statistics, China, China Statistics Press.

8) Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Intergovernmental Panel on Climate Changes, 1997.

9) Energy Utilization and Earth environment for Asia, National Institute of Science and Technology Policy of Japan, 1992.

10) Higashino, H., Tonooka, Y.: Emission inventory of air pollutants in East Asia (II)- Focused on Estimation of NOx and CO2 Emission in China, *Japan Society of Atmosphere Environment*, Vol. 31, No. 6, pp. 262-281, 1996.