NISTEP REPORT No.21

ANALYSIS OF THE STRUCTURE OF ENERGY CONSUMPTION AND THE DYNAMICS OF EMISSIONS OF ATMOSPHERIC SPECIES RELATED TO THE GLOBAL ENVIRONMENTAL CHANGE (SO_X, NO_X & CO_2) IN ASIA

SUMMARY

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Research Group on Energy Consumption in Asia and the Global Environment

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CONTENTS

Introduction

This report summarizes "NISTEP REPORT No. 21 Analysis of the Structure of Energy Consumption and the Dynamics of Emissions of Atmospheric Species Related to the Global Environmental Change (SOx, NOx & CO_2) in Asia," with the following background, objectives, and the organizations to proceed with the research and studies.

It is widely ackowledged with deep concern that an increase of the world population and an expansion of the sphere of human activities will affect our global environment.

The Asian region, accounting for about 60 percent of the world population, where an increase in population and energy consumption in accordance with an expansion of economic activities are expected, is regarded with anxiety as one of the regions which will have the fastest increase of loads on the global environment. This region has, however, been regarded as one of the most difficult areas in which to grasp the actual state because social and economic conditions differ widely between by countries and economies such as in developing countries, NIEs, centrally-planned economies,etc. in addition to the geographically vast extent of the area.

For this reason, in this report,the structures of energy consumption and the dynamics of emissions of atmospheric species which will affect the global environment (SOx, NOx, and CO_2). in the whole Asian region (25 countries) east of Afghainistan and Pakistan will be reviewed geographically as a basic study for the global environmental changes resulting from the use of energy. in particular, this report aims to provide basic information in order to design environmental policies in developing countries.

This report summarizes historical records from a study which covered historical records and future trends, though there are many assumptions in view of the limitations on the reliability of the available energy data and an accuracy of detailed data and information collected through our field surveys such as properties of fuels consumed, conditions of fuel combustion, etc. In this report, we try to contribute to the efforts to grasp more accurately future states of affair by describing these assumptions clearly.

The "Research Group on Energy Consumption in Asia and the Global Environment "(Est. March, 1991) and the "Sub-committee for Estimation of Emissions of

Atmospheric Environment Pollutants Resulting from Energy Consumption in Asia "(Est. October, 1989)" consist of many scholars and experts to whom we wish to express appreciation for continuing useful advice and cooperation.
we are also grateful to other individuals concerned with this study and hope to develop it with their continuing cooperation.

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NISTEP REPORT No. 21

A Summary of

Analysis of the Structure of Energy Consumption and the Dynamics of Emissions of Atmospheric Species Related to the Global Environmental Change (SOx, NOx & CO2) in Asia

OUTLINE

This report makes clear geographically the structure of energy consumption and the dynamics of emissions of SOx, NOx, and CO_2, which are the main substances affecting global environmental changes (global acidification and greenhouse effect) resulting from the use of energy covering the Asian region (25 countries) east of Afghainistan and Pakistan.

We made a survey for the period from 1975 to 1987, dividing China and India, into 29 and 13 areas respectively to grasp the situation on an equivalent geographical scale to the other countries.

Some of the characteristics of this report are: first, this report has been on the basis of the detailed energy balance tables, including vegetal fuels in developing countries, released for the first time by IEA/OECD. in particular, we developed detailed energy balance tables for China in this study based on the data obtained through our inquiries to the Chinese National Statistics Bureau. This is the very first approach to energy analysis of the whole Asian region based upon detailed energy data including vegetal fuels.

As a second characteristic, this study for the first time makes an estimate of emmissions of SOx, NOx, and CO_2 in the whole area of 25 countries in Asia by country including China and India and shows the trends of these emissions (See Tables-1 and -2).

Third, by dividing the energy consumption sector into 17 sub-sectors and fuels into 27 kinds, we make a review for an application of emission factors of SOx and NOx, and emission factors of CO_2 by 27 kinds of fuels to each country or area, and describe the basis for the estimate in detail. This report thus could serve as data for the analysis of the trend and the basis for planning environmental policies in Asian countries.

Table 1. An Estimate of SOx Emissions from Asian Countries

(Unit: 1000 ton/year)

Countries	Emission Estimates of This Survey					Emission Estimates of Other Surveies				
	1975年	1980	1985	1986	1987	1975	1980	1985	1986	1987
1,China	10,175	13,372	17,259	18,326	19,989		①'81 13,710	① 13,250	①12,500 ②18,972 ⑧15,840	① 14,120
2,Japan	2,571	1,604	1,175	1,088	1,143	③ 2,586	③ 1,263	③'83 1,049	③ 835 ⑧ 1,120	
3,India	1,652	2,010	2,833	2,921	3,074				② 3,181	
4,Indonesia	201	329	435	453	485				② 780	
5,S.Korea	1,159	1,918	1,366	1,355	1,294			④ 1,352	② 1,224 ⑧ 1,350	⑨ 1,041
6,N.Korea	234	271	324	333	333				② 587 ⑧150-700	
7,Taiwan	609	1,036	693	744	605				② 850 ⑧ 340	⑤'88 1,368
8,Thailand	224	420	507	528	612		⑥'82 317		② 627	
9,Pakistan	148	198	351	345	381				② 748	
10,Philippines	807	1,041	510	447	370				② 403	
11,Malaysia	193	272	271	264	263				② 298	⑦ 268
12,Bangladesh	40	57	46	51	49				② 150	
13,Vietnam	40	34	38	38	39					
14,Hong Kong	109	166	144	149	150				② 274	
15,Singapore	85	122	147	151	155				② 61	
16,Nepal	3.7	4.9	7.6	11.3	11.0					
17,Myanmar	17.4	30.9	30.0	32.3	29.9					
18,Sri Lanka	22.3	30.0	23.5	22.6	28.2					
19,Afghanistan	8.1	8.5	8.6	7.5	10.7					
20,Mongolia	38.7	65.1	89.7	97.0	100.5					
21,Brunei	0.4	0.9	1.1	1.0	1.1					
22,Kampuchea	1.2	1.3	2.8	2.9	2.9					
23,Laos	1.3	1.4	1.6	1.7	1.7					
24,Moldives			0.3	0.3	0.3					
25,Macau	0.9	3.0	6.2	7.1	8.4					
Asia Total	18,340	22,997	26,269	27,377	29,136					

Remarks: Sphere of Estimates
(1) All energy consumption excluded intl. marine bunkers, but China excludes aviation.
(2) Non-ferrous metal refining and sulfuric acid production

Source: ① Chinese Statistics Yearbook 1988 etc. ② ACID RAIN IN ASIA: AN ECONOMIC, ENERGY AND EMISSIONS OVERVIER: by Wesly K. Foell and Collin W. Green: Resource Management Associates of Madison, Inc. University of Wisconsin, Asian Institute of Technology: 19 November 1990. ③ OECD ENVIRONMENTAL DATA COMPENDIUM 1991 OECD. ④ White Paper on the Environmet, Environmet Agency of Korea ⑤ White Paper on the Environmet of Taiwan ⑥ THAILAND NATURAL RESOURCES PROFILE: Thailand Development Research Institute, May 1987. ⑦ Department of Environment, Environmental Quality Report, 1987 Malaysia. ⑧ SO2 Emissions Estimates of East Asia, 1989, Shinichi Fujita yooichi Ichikawa, Central Research Institute of Electric Power Industry ⑨ Environmental Yearbook in Korea 1988,'89,90, Environment Agency of Korea

Table 2. An Estimate of NOx Emissions from Asian Countries

(Unit: 1000 ton/year)

Countries	Emission Estimates of This Survey					Emission Estimates of Other Surveies				
	1975	1980	1985	1986	1987	1975	1980	1985	1986	1987
1,China	3,727	4,907	6,361	6,772	7,371		①'81 4,401		② 7,671	
2,Japan	2,329	2,132	1,948	1,901	1,935	③ 1,781	③ 1,400	③'83 1,367	③ 1,176	
3,India	1,379	1,673	2,312	2,401	2,556				② 2,830	
4,Indonesia	331	465	561	600	639				② 712	
5,S.Korea	220	365	464	499	555			④ 723	② 663	⑧ 837
6,N.Korea	325	383	456	468	468				② 628	
7,Taiwan	124	225	261	300	325				② 298	⑤'88 636
8,Thailand	182	255	327	341	384		⑥'82 153		② 495	
9,Pakistan	101	164	193	201	231				② 119	
10,Philippines	172	184	173	177	184				② 202	
11,Malaysia	90	126	167	171	177				② 296	⑦ 95
12,Bangladesh	46	58	61	65	66				② 25	
13,Vietnam	120	88	95	98	99					
14,Hong Kong	51	67	106	119	134				② 111	
15,Singapore	43	67	81	84	88				② 166	
16,Nepal	18	21	34	53	50					
17,Myanmar	38	47	50	53	45					
18,Sri Lanka	23	31	34	33	37					
19,Afghanistan	20	22	24	22	30					
20,Mongolia	31	49	66	71	72					
21,Brunei	2.0	4.0	8.1	7.7	11.1					
22,Kampuchea	8.6	9.3	11.7	12.1	12.3					
23,Laos	7.9	8.0	8.7	8.9	9.1					
24,Moldives			0.5	0.6	0.6					
25,Macau	2.1	2.9	3.7	4.8	5.0					
Asia Total	9,388	11,352	13,805	14,462	15,483					

Remarks: Sphere of Estimates
(1) All energy consumption excluded intl. marine bunkers, but China excludes aviation.

出典) ① Chinese Social Statistics Yearbook 1987 ② ACID RAIN IN ASIA: AN ECONOMIC, ENERGY AND EMISSIONS OVERVIER: by Wesly K. Foell and Collin W. Green: Resource Management Associates of Madison, Inc. University of Wisconsin, Asian Institute of Technology: 19 November 1990. ③ OECD ENVIRONMENTAL DATA COMPENDIUM 1991 OECD. ④ White Paper on the Environmet, Environmet Agency of Korea ⑤ White Paper on the Environmet of Taiwan ⑥ THAILAND NATURAL RESOURCES PROFILE: Thailand Development Research Institute, May 1987. ⑦ Department of Environment, Environmental Quality Report, 1987 Malaysia. ⑧ Environmental Yearbook in Korea 1988,'89,90, Environment Agency of Korea

In developing of this study, we received useful advice and cooperation from the members of the "Research Group on Energy Consumption in Asia and the Global Environment " (Chairperson: Junpei Andou, Professor, Chuo University, with 10 other members) and the "Sub-Committee for Estimation of Emissions of Atmospheric Environment Pollutants Resulting from Energy Consumption in Asia "(Chairperson: Junpei Andou, Professor, Chuo University, with 10 other members) which were established for this purpose and consist of experts from various fields.

I. Background and Objectives

The Asian region, accounting for about 60 percent of the world population, where an increase in population and energy consumption relative to an expansion of economic activities is expected, is regarded with anxiety as one of the regions which will have the fastest increase of loads on the global environment. The region has, however, been regarded as one of the most difficult areas in which tograsp the actual state.

For this reason, in this report, by reviewing geographically the historical trends of the structures of energy consumption and the dynamics of emissions of the main substances, such as SOx, NOx, and CO_2 ,which affect the global environment (global acidification and greenhouse effect), in the Asian region as a whole (25 countries) east of Afghainistan and Pakistan, we have prepared basic data and information for planning global environmental measures. Also, this report provides basic data and information for the development of environmental policies in developing countries where air pollution has been aggravated.

II. Subjects and Procedures of the Study

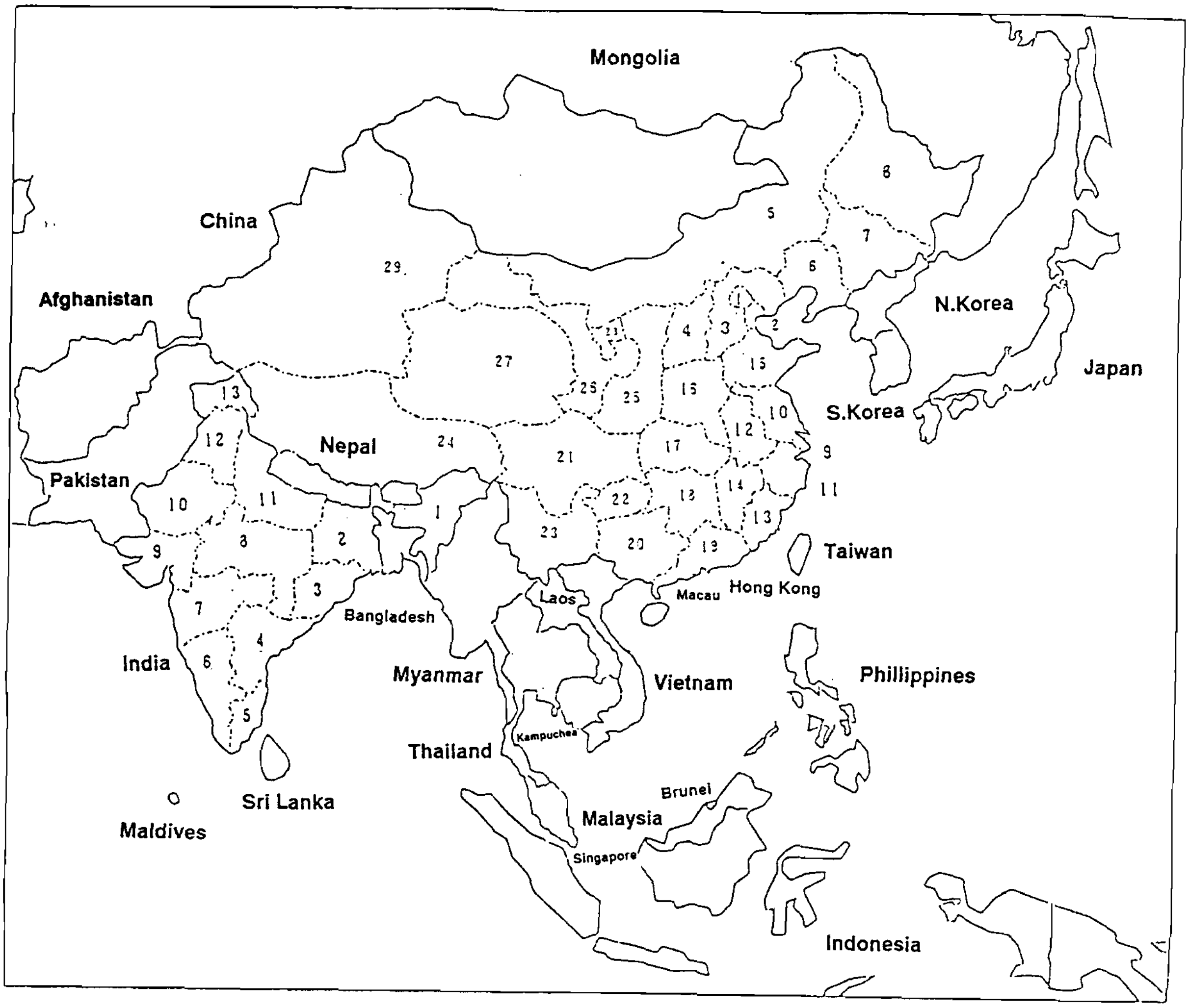
1. Areas Surveyed

This report covers 25 Asian countries and divides China and India into 29 and 13 areas respectively in the estimation of the SOx, NOx, and SO2 emissions,attaching importance to their local characteristics. Further, Taiwan, Hong Kong and Macau are regarded as countries for the purpose of this report, (See Figure-1).

2. Years Surveyed

Twelve years for the period from 1975 to 1987 are surveyed in this report.

Fig. 1. Asian Region of This Survey



States of China

1	Beijing	16	Henan
2	Tianjin	17	Hubei
3	Hebei	18	Hunan
4	Shanxi	19	Guangdong
5	Inner Mongolia	20	Guangxi
6	Liaoning	21	Sichuan
7	Jilin	22	Guizhou
8	Heilongjiang	23	Yunnan
9	Shanghai	24	Tibet
10	Jiangsu	25	Shaanxi
11	Zhejiang	26	Gansu
12	Anhui	27	Qinghai
13	Fujian	28	Ningxia
14	Jiangxi	29	Xinjiang
15	Shandong		

States of India

1 Assam, Manipur, Megahalaya, Nagaland, Tripura, Arunachal Pradesh, Mizoram
2 Bihar, Sikkim, West Bengal
3 Orissa
4 Andhra Pradesh
5 Tamil Nadu, Pondicherry, A.N.Islands
6 Karnataka, Kerala, Lakshadweek
7 Maharashtra, D.N., Goa, Daman, Diu
8 Madhya Pradesh
9 Gujarat
10 Rajasthan
11 Uttar Pradesh, Delhi
12 Haryana, Himarchal Pradesh, Punjab, Chandigarh
13 Jammu, Kashmir

3. Energy Data Used and Analysis of Energy Consumption Structures

(1) Energy Data Used

This report is based mainly on OECD/IEA Energy Balance Table ("World Energy Statistics and Balance" and "Energy Balance of OECD Countries") including vegetal fuels, such as fuelwood, charcoal, bagasse, etc. which are a main source of enegry in developing countries. For Afghanistan, Mongolia , Cambodia, Laos, Mardives, and Macau, which now lack such statistics, we used statistics from " UN Energy Statistics Yearbook 1987." As for the figures for China after 1980, we made a detailed energy balance sheet for use in the analysis by obtaining necessary data through inquiries to the Chinese National Statistics Bureau based upon "Chinese Energy Statistics Yearbook 1989, Chinese National Statistics Bureau" (See Table-3).

(2) Analysis of Energy Consumption Structures

We have analyzed energy consumption structures in Asian countries for 6 main energy sources, i.e. coal, oil, natural gas, nuclear electricity, hydro electricity, etc., and vegetal fuels, and for 4 sectors in the energy consumption sectors, i.e. industrial, transportation, and " other" sectors in the final consumption sector, and the electricity generation sector in the energy conversion sector. All energies are expressed in tons oil equivalent(toe).

4. Eitted Substances Analyzed and Estimates of their Emission Sources and Emitted Amouns

(1) Substances Analysed

In this study, SOx and NOx have been analysed as substances related to global acidification (mainly acid rain), and CO_2 as a substance related to the greenhouse effect, which are emitted as a result of energy consumption. Furthermore, NOx is known to be related to the formation of photochemical smog (the main component is ozone), and ozone in turn with destruction of plants and the greenhouse effect.

Emission sources are analysed for emissions resulting from energy consumption (except for international marine bunkers and non-energy use of fuels, such as feedstocks for petrochemicals, lubricating oils, etc.) and the emissions from raw materials in various industrial processes; i.e. non-ferrous metal smeltering, sulfuric acid production (SOx),and cement manufacturing (CO_2).

Table 3. Energy Consumption Sectors and Energy Sources of This Survey

Energy Comsuption Sectors

Energy Comsuption Sectors	Detailed Sectors
Transformation Sector	Patent Fuel and BKB Plants
	Coke Ovens
	Gas Works
	Oil Refineries
	Electric Generation
	Non Specified Transformation
	Own Use
Industrial Sector	Iron and Steel
	Chemical and Petorchemical
	Non-Metallic Minerals
	Others and Non Specified
Transport Sector	Civil Aviation
	Road Transport
	Railways
	Navigation and Others
Other Sector	Residential
	Agriculture, Commerce etc.

Energy Sources

Energy Sources	Detailed Fuels
Coal	Hard Coal
	Brown Coal
	Coke
	Patent Fuel
	BKB
	COG
	BFG
Gas	GWG
	Natural Gas
Oil	Crude Oil
	NGL
	Refinery Gas
	LPG
	Aviation Gasoline
	Motor Gasoline
	Jet Fuel
	Kerosene
	Diesel Oil
	Residual Oil
	Naphtha
	Other Products
Nuclear	Electricity
Hydro/ Other	Electricity
Electricity	Electricity
Heat	Heat
Vegetal Fuels	Bagasse
	Fuelwood
	Charcoal
	Peat
	OTHER Non-Commercial Fuels

Remarks:

1. Countries by These Energy Consumption, Energy Sources and Data Source (19 Countries).
   1)WORLD ENVERGY STATISTICS AND BALANCES OECD/IEA 1971-1988 1990
   China(1975), India, Indonesia, S.Korea, N.Korea, Taiwan, Thailand, Pakistan, Philippines, Malaysia, Bangladesh, Vietnam, Hong Kong, Singapore, Nepal, Myanmar, Sri Lanka, Brunei
   2)ENERGY BALANCES OECD COUNTRIES OECD 1971-1988
   Japan
   3)Chinese Energy Statistics Yearbook 1989, Chinese National Statistics Bureau
   China(1980-1987)
1. Countries by This Energy Sources (non-Energy Consumption Sectors) and Data Source(6 Countries).
   1)ENERGY STATISTICS YEARBOOK 1987 United Nations 1987
   Afghanistan, Mongolia, Kampuchea, Laos, Maldives, Macau

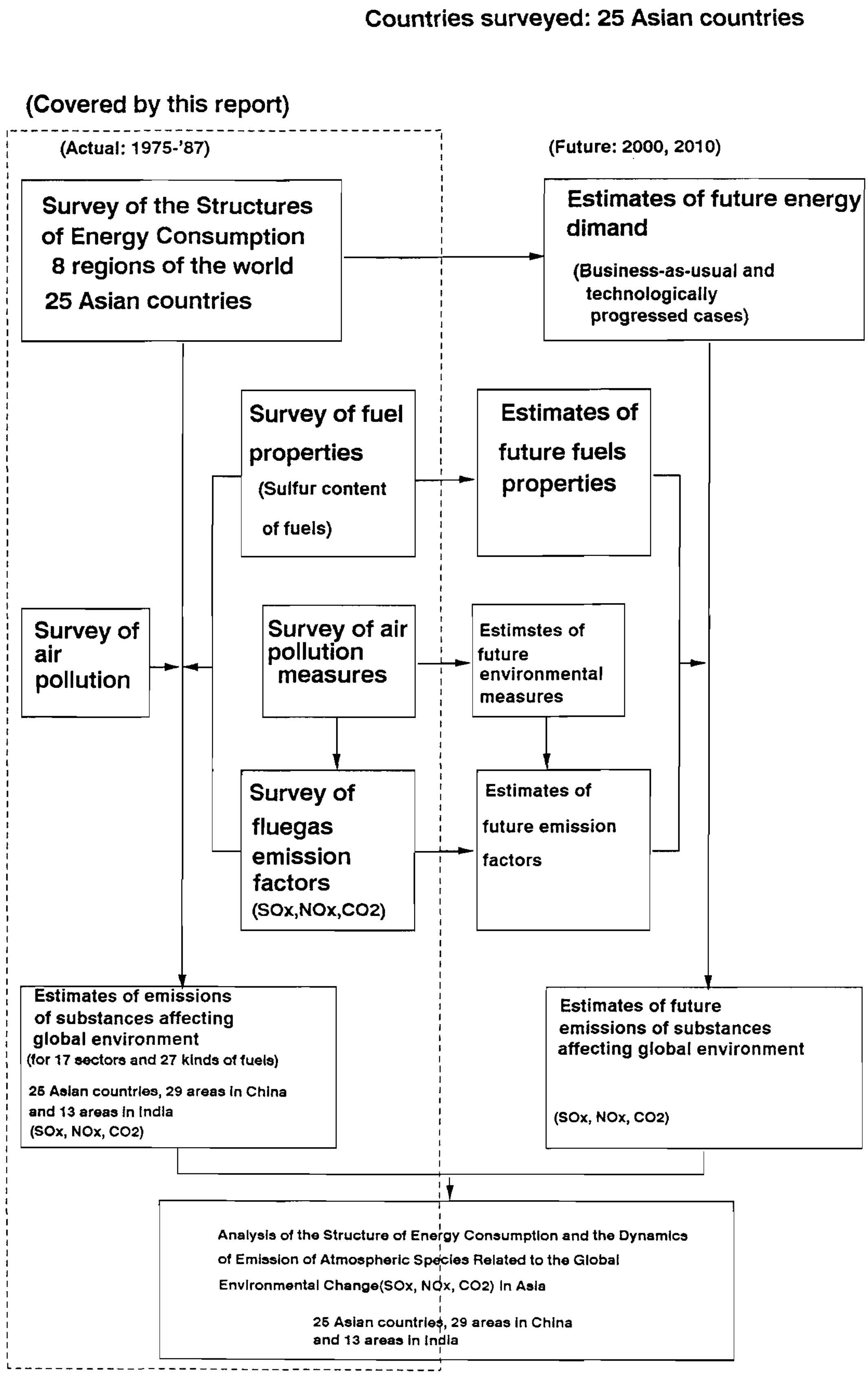
(2) Method of Emission Estimates

Emissions of SOx, NOx and CO_2 by country have been estimated for each of the 27 fuels and of the 17 sectors by multiplying volumes of fuel consumed by the emissions per unit of fuel consumption (emission factors). For this purpose, we analyzed sulfur contents of fuels for emission factors of SOx and developed emission factors for NOx applicable to Asian countries based on the studies of The Japan Environmental Agency (JEA), the Tokyo Metropolitan Government, and Environment Protection Agency (EPA) of the United States. Further, CO_2 factors have been developed on the basis of the results of a study on the average content of carbon (C) by fuels made by Oak Ridge Associated Universities, Inc., etc.

Estimates of the SOx, NOx and CO_2 emissions by areas within China and India have been made by allocating estimated amounts of emissions of the whole country to each area within the country on the basis of sectoral indicies of iron & ore production, etc.

Also, we made fact-finding trips to China, India, Thailand and South Korea to collect data and information concerning this study.

Fig. 2. Flowchart of the Whole Survey



III. The Result of the Survey

1. Characteristics of Energy Consumption in the Asian Region

(1) Socio-Economic Indices and Primary Energy Consumption

① The Asian regions proportion world population in 1987 was remarkably high at 57 percent (56 percent in 1975). In contrast, GDP in real terms and the primary energy consumption were still low at 17 percent (13 percent in 1975) and 20 percent (17 percent in 1975) respectively. The Asian region, however, is the region enjoying the fastest expansion of its economy and primary energy consumption in the world as shown in an increase in the shares of real GDP and energy consumption (See Table-4).

② The primary energy consumption in Asia had been increased to 1,620 million toe in 1987 from 1,040 million toe in 1975 with the average annual growth rate of 3.8 percent exceeding 2.4 percent world average growth rate . Though this growth rate was below those of Middle Eastern, African, and Latin American regions, the amount increased was the largest, at 580 million toe, in the world.

③ Since energy consumption per capita in Asian region at 597 kg toe in 1987 was the least in the world, one-third of that in the world and one-thirteenth of that of North America, growth potentials for energy demand are high (See Figure-3).

④ The primary energy intensity against GDP (= the average annual rate of increase of the primary energy consumption/the average annual rate of increase of GDP) in Asia in the period from 1975 to ´87 was 0.7 and was below the world average of 0.8 indicating that energy conservation in this region had been more in progress than the world average.

(2) Primary Energy Consumption by Energy Sources

① In the energy consumption by sources in Asia, the average annual rates of increase for coal (5.1%), gas (11.6%), and nuclear energy (19.7%) exceeded that of the total primry energy consumption. in particular, coal consumption amounted to 699 million toe in 1987 and exceeded 595 million toe in USSR-East European countries making this region the largest consumer of coal with the share of 32% in the world.

Moreover, coal accounted for the highest share of 43 % replacing oil in energy consumption by sources in Asia which made Asia the only region with the highest share of coal in the energy mix (See Figure-4).

② Asia was also the largest consumer of vegetal fuels with 38 % share of the world

Table 4. Population, GDP and Primary Energy Consumption: Macro Regions

Macro regions	Date						Regional percentages						Annual rate of in-crease 1975-'87(%)		
	Population (millions)		GDP (billions of u.s.$ '85)		Primary energy consumption (M toe)		Population		GDP		Primary energy consumption		Popula-tion	GDP	Primary energy consump-tion
	1975	1987	1975	1987	1975	1987	1975	1987	1975	1987	1975	1987			
Asia	2,196	2,714	1,428	2,644	1,036	1,620	56.4	56.7	13.3	17.4	17.2	20.1	1.8	5.3	3.8
Oceania	17	20	138	192	73	95	0.4	0.4	1.3	1.3	1.2	1.2	1.2	2.8	2.1
Middle East	119	171	367	476	74	214	3.1	3.6	3.4	3.1	1.2	2.7	3.1	2.2	9.3
Africa	307	449	274	377	181	302	7.9	9.4	2.6	2.5	3.0	3.8	3.2	2.7	4.4
Latin America	291	384	510	722	309	487	7.5	8.0	4.8	4.7	5.1	6.1	2.3	2.9	3.9
North America	239	270	3,238	4,633	1,868	2,100	6.1	5.6	30.2	30.4	30.9	26.1	1.0	3.0	1.0
Western Europe	343	356	2,323	3,066	1,114	1,317	8.8	7.4	21.6	20.1	18.4	16.4	0.3	2.3	1.4
E.Eur.exc.USSR	384	422	2,453	3,121	1,387	1,905	9.9	8.8	22.9	20.5	23.0	23.7	0.8	2.0	2.7
World Total	3,896	4,785	10,731	15,232	6,042	8,039	100.0	100.0	100.0	100.0	100.0	100.0	1.7	3.0	2.4
OECD	710	767	6,558	9,318	3,381	3,880	18.2	16.0	61.1	61.2	55.9	48.3	0.6	3.0	1.2
CPE	1,372	1,587	2,650	3,582	1,794	2,612	35.2	33.2	24.7	23.5	29.7	32.5	1.2	2.5	3.2
DC	1,813	2,431	1,523	2,332	868	1,547	46.6	50.8	14.2	15.3	14.4	19.2	2.5	3.6	4.9
World Total	3,896	4,785	10,731	15,232	6,042	8,039	100.0	100.0	100.0	100.0	100.0	100.0	1.7	3.0	2.4

a) Primary energy consumption includes vegetal fuels.
Sources: "International Financial Statistics", Mar.1988, IMF.
"Energy Balances of OECD Countries" "World Energy Statistics and Balances", 1971-1988, OECD/IEA.

Fig. 3. Relations between Economic Levels and Primary Energy Consumption per Capita in the world by Regions

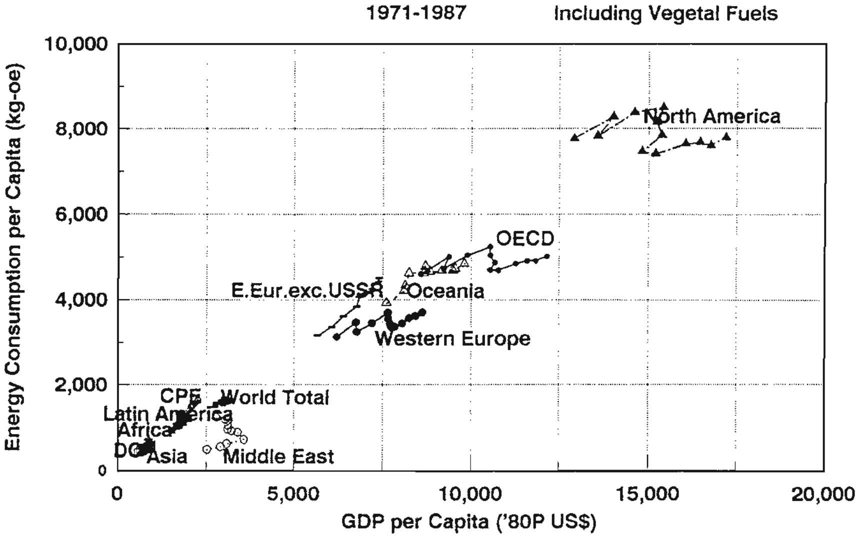
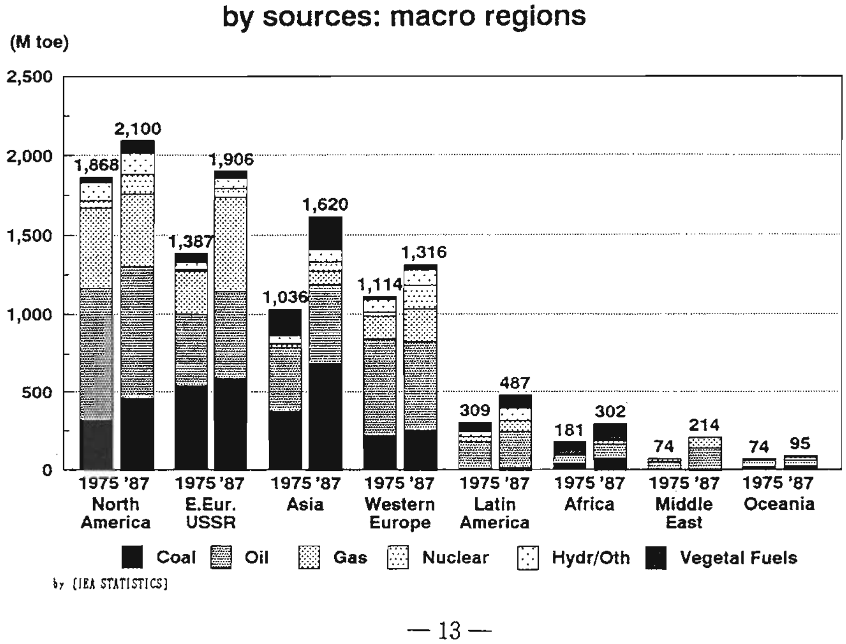


Fig. 4. Amounts of primary energy consumption by sources: macro regions



by (IEA STATISTICS)

in 1987 being increased by 1.8% annually on the average in the period between 1975 and 1987. It is feared that this will increase loads on the global environment in addition to the use of coal.

2. Structures and the Trends of Energy Consumption in Asia

(1) Socio-Economic Indices and Primary Energy Consumption

① The average annual growth rate of primary energy consumption in Asian countries in the period between 1975 and 1987 were high at more than 6% in Asian NIES, etc. and between 5 and 6% in China, India, etc. Japan and some other countries, however, remained low at between 1 and 2%.

② In 1987, China accounted for 40% of the total primary energy consumption in Asia, Japan was at 23%, and, adding India, Indonesia, South Korea, North Korea, and Taiwan, these seven countries accounted for 90% of the Asian total and the remaining 18 countries 10%. Thus, the energy consumption in Asia differs widely by country.

③ Primary energy consumption per capita in most Asian countries has increased in accordance with improvements in the levels of their economies (i.e. GDP per capita) and is increasing further following the course of the increase in Japan, Singapore, etc. (See Figure-5)

④ Energy intensities, which indicate relations between the annual average growth rates of GDP and primary enrgy consumption, were 0.3 in Japan and 0.6 in China against 0.7 for the total Asian countries indicating that energy conservation had progressed in these countries, but were between 0.9 and 1.1 for Asian NIEs and the main developing countries indicating that the growth rate of GDP and the energy consumption were on the similar level in these countries.

(2) Primary Energy Consumption by Sources of Energy (See Figure-6)

① In the country-by-country review of the trends of the mix of three energy sources, i. e. fossil fuels, primary electricity, and vegetal fuels, out of the primary energy consumption by energy sources in Asia, South Asian and Southeast Asian countries had more than a 50% share in vegetal fuels, but have been changing in the direction of decreasing their share and increasing the share of fossil fuels. Consumption of vegetal fuels in Asian region as a whole, however, has increased at an average annual rate of 1.8%. The share of vegetal fuels in primary energy consumption has been on the decrease in accordance with the

Table 5. Population, GDP and Primary Energy Consumption: Asian Countries

Macro regions	Date: Population (millions) 1975	Date: Population (millions) 1987	Date: GDP (billions of u.s.$ '80) 1975	Date: GDP (billions of u.s.$ '80) 1987	Date: Primary energy consumption (M toe) 1975	Date: Primary energy consumption (M toe) 1987	Regional percentages: Population 1975	Regional percentages: Population 1987	Regional percentages: GDP 1975	Regional percentages: GDP 1987	Regional percentages: Primary energy consumption 1975	Regional percentages: Primary energy consumption 1987	Annual rate of increase 1975-'87(%): Population	Annual rate of increase 1975-'87(%): GDP	Annual rate of increase 1975-'87(%): Primary energy consumption
1,China	933.0	1,088.6	184.6	470.2	354.6	648.6	42.0	39.6	12.9	17.7	34.2	39.8	1.3	8.1	5.2
2,Japan	111.6	122.1	831.5	1,370.7	326.4	371.7	5.0	4.4	58.2	51.7	31.5	22.8	0.8	4.3	1.1
3,India	600.8	781.4	148.4	250.6	145.1	228.5	27.0	28.4	10.4	9.5	14.0	14.0	2.2	4.5	3.9
4,Indonesia	130.5	170.2	54.2	100.9	37.7	67.9	5.9	6.2	3.8	3.8	3.6	4.2	2.2	5.3	5.0
5,S.Korea	35.3	41.6	43.1	111.7	28.0	66.1	1.6	1.5	3.0	4.2	2.7	4.1	1.4	8.3	7.4
6,N.Korea	15.9	21.4			29.3	42.1	0.7	0.8			2.8	2.6	2.5		3.1
7,Taiwan	16.2	19.7	25.1	71.9	15.1	37.8	0.7	0.7	1.8	2.7	1.5	2.3	1.7	9.2	8.0
8,Thailand	41.9	53.6	22.0	47.5	18.6	30.5	1.9	1.9	1.5	1.8	1.8	1.9	2.1	6.6	4.2
9,Pakistan	71.0	102.2	20.5	43.5	13.3	28.7	3.2	3.7	1.4	1.6	1.3	1.8	3.1	6.5	6.6
10,Philippines	42.1	57.4	26.0	36.3	17.7	20.5	1.9	2.1	1.8	1.4	1.7	1.3	2.6	2.8	1.2
11,Malaysia	11.9	16.5	16.3	33.5	7.6	17.9	0.5	0.6	1.1	1.3	0.7	1.1	2.8	6.2	7.4
12,Bangladesh	79.0	102.6	12.4	19.0	6.8	10.7	3.6	3.7	0.9	0.7	0.7	0.7	2.2	3.7	3.9
13,Vietnam	47.6	62.8	4.7	7.1	10.1	10.5	2.1	2.3	0.3	0.3	1.0	0.6	2.3	3.6	0.3
14,Hong Kong	4.4	5.6	15.4	45.8	4.3	9.1	0.2	0.2	1.1	1.7	0.4	0.6	2.1	9.5	6.6
15,Singapore	2.3	2.6	7.8	17.5	4.2	8.6	0.1	0.1	0.5	0.7	0.4	0.5	1.2	7.0	6.2
16,Nepal	12.6	17.8	1.7	2.7	2.9	8.2	0.6	0.6	0.1	0.1	0.3	0.5	2.9	3.7	9.1
17,Myanmar	30.2	39.1	4.3	6.4	4.6	5.9	1.4	1.4	0.3	0.2	0.4	0.4	2.2	3.3	2.2
18,Sri Lanka	13.5	16.4	3.2	5.6	2.7	3.7	0.6	0.6	0.2	0.2	0.3	0.2	1.6	4.9	2.5
19,Afghanistan	11.8	15.2	2.6	3.0	2.7	3.3	0.5	0.6	0.2	0.1	0.3	0.2	2.2	1.2	1.8
20,Mongolia	1.42	2.03	0.83	1.64	1.53	3.01	0.1	0.1	0.1	0.1	0.1	0.2	3.0	5.8	5.8
21,Brunei	0.16	0.23	2.99	3.65	0.21	2.11	0.0	0.0	0.2	0.1	0.0	0.1	3.4	1.7	21.3
22,Kampuchea	7.10	7.68			1.37	1.81	0.3	0.3			0.1	0.1	0.7		2.4
23,Laos	3.43	3.78			1.12	1.47	0.2	0.1			0.1	0.1	0.8		2.3
24,Moldives	0.13	0.20		0.08		0.03	0.0	0.0		0.0	0.0	0.0	3.4		
25,Macau	0.27	0.43			0.11	0.33	0.0	0.0			0.0	0.0	4.0		9.9
Asia Total	2,223.8	2,751.0	1,427.5	2,649.4	1,035.8	1,628.9	100.0	100.0	100.0	100.0	100.0	100.0	1.8	5.3	3.8

a) Primary energy consumption includes vegetal fuels

Sources: "Demographic Yearbook", UN. "Statistical Yearbook of the Republic of China", 1989, The Republic of China.
"National Accounts Statistics: Analysis of Main Aggregates", UN.
"Energy Balances of OECD Countries" "World Energy Statistics and Balances", 1971-1988, OECD/IEA. "Energy Statistics Yearbook", UN. Chinese Statistics Report of Energy Resouces 1989", The State Statistics Bureau of China.

Fig. 5. Relations between Economic levels and Primary Energy Consumption per Capita in Asia by Countries Including Vegetal Fuels

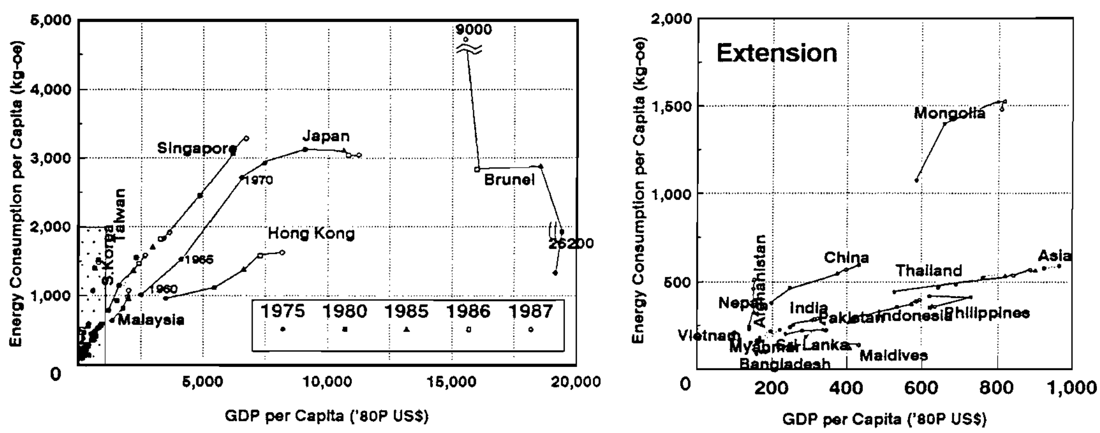
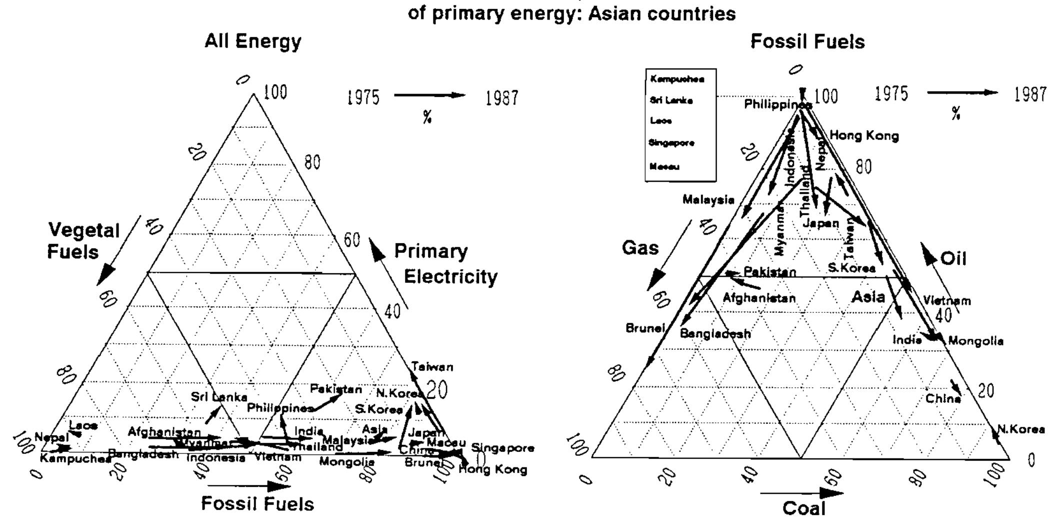


Fig. 6. Transitions of component ratios of primary energy: Asian countries



improvement in the level of economy (GDP per capita), and, in comparison to the trends in various countries, it is found out that when GDP per capita exceeded some 3,000 US dollars (1980 US dollar), the levels of Taiwan and South Korea in 1987, the dependence on vegetal fuels became nil (See Figure-7).
Meanwhile, the share of primary electricity generated by hydraulic and nuclear powers has been on the increase in the Philippines, Pakistan, Japan, South Korea, Taiwan, etc., and there was a shift in the trend of dependency from vegetal fuels to fossil fuels and further to primary electricity generation in Asian countries.

② From 1975 to 1987, the trend of coal, oil, and gas in the fossil fuel mix in Asian countries as a whole showed an increase in the share of coal (1975: 37%, 1987: 43%) and gas (1975: 2%, 1987: 5%) at the cost of oil(1975: 40%, 1987: 31%), which meant that the 9% decrease in the share oil had been substituted by coal and gas with 6% and 3% respectively.

From a country-by-country review, it was found out that there were both extremes to lower the share of oil: while some countries, such as Malaysia, Bangladesh, Indonesia, Myanmer, etc. have increased the share of gas, others such as Taiwan, South Korea, Hong Kong, China, etc. increased the share of coal, and there were countries like Japan and Thailand who increased both gas and coal.

(3) Trends in Energy Consumption by Sector

1) Final Energy Consumption Sector

① Regarding the trends in the share of the three sectors, i. e. the industrial, transportation, and " other" sectors, in the final energy consumption, South Asian and Southeast Asian countries in which " other" sector accounted for more than 50% have made a shift to the industrial sector from " other" sector and South Korea, Malaysia, etc. to the industrial and transportation sectors from " other" sector. In Japan and North Korea, an increase in the shares of transportation and " other" sectors from the industrial sector was observed (See Figure-8).

② It was discvered that the economic level (per capita GDP) and the share of "other" sector which included demand for residential and other uses in final energy consumption (in 1987) were closely related. Nepal, Myanmar, and Bangladesh having small GDP per capita had a large share of residential and other uses with over 70%, and it was found out that the share of " other"

Fig. 7. Relations between Economic Levels and the Share of the Vegetal Fuels in the Primary Energy Consumption

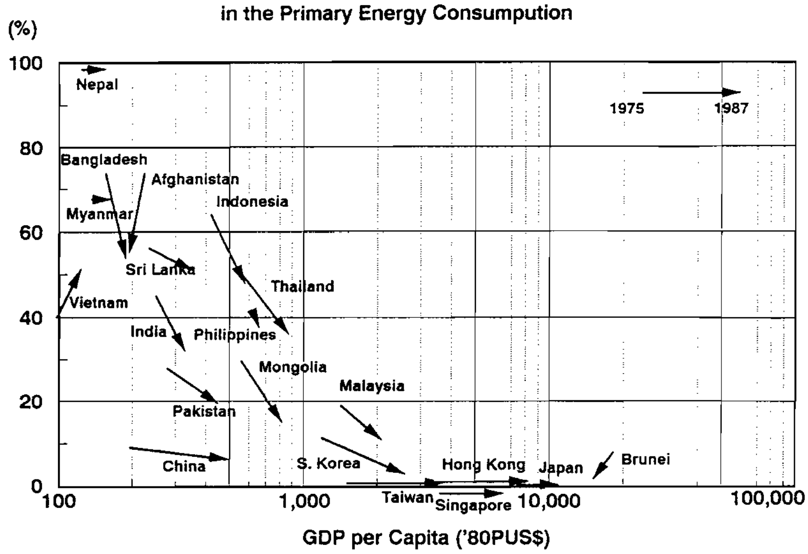


Fig. 8. Trends in the Composition of the Final Energy Consumption in Asia by Countries

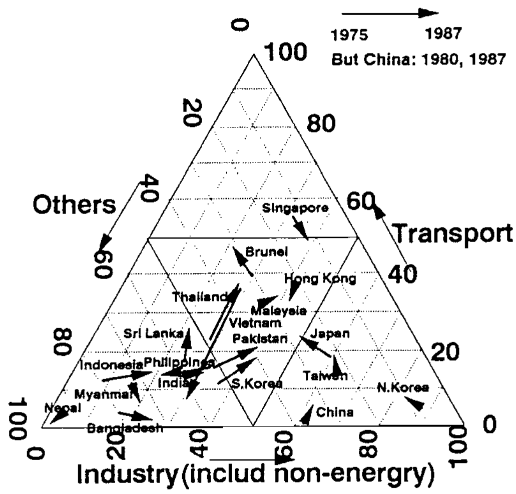


Fig. 9. Relations between Economic Levels and the Share of The Other Sector (Residential etc.)in the Final Energy Consumption

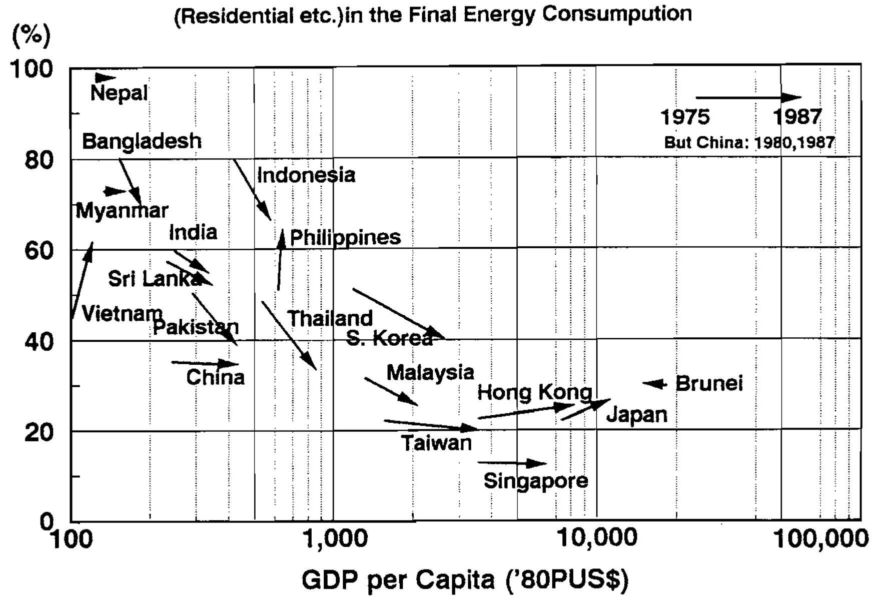
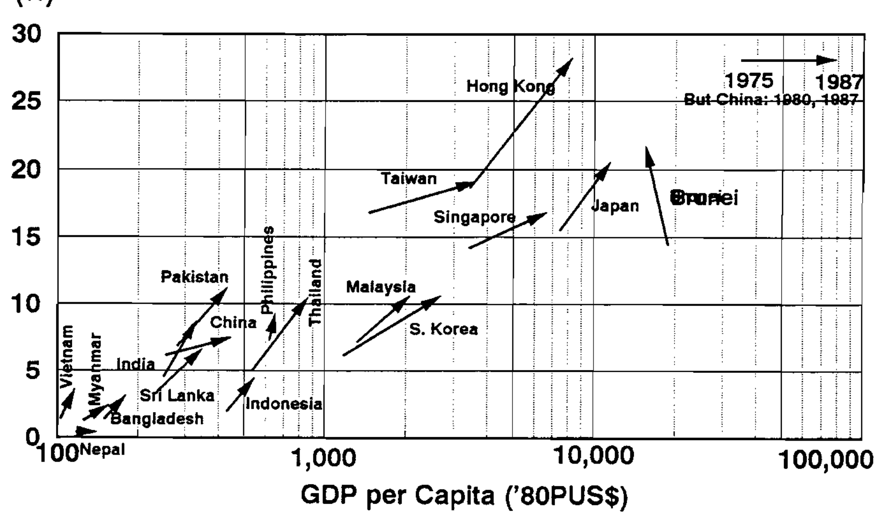


Fig. 10. Relations between Economic Levels and the Rate of Electricification



sector decreased with the extent of industrialization in the order from South Asian low-income countries, ASEAN countries in Southeast Asia, and NIEs. On the contrary, in Japan and Brunei, the share of " other" sector increased, and a turning point from decrease to increase seemed to be some 8,000 dollars (1980 US dollar) of GDP per capita which is the level enjoyed by Singapore and Hong Kong at present (See Figure-9).

③ The share of elecricity consumption in final energy consumpyion (the rate of electrification) becomes larger with the improvement of economic levels (GDP per capita). In Nepal, Myanmar, and Viet Nam, the rate of electrification was as low as less than 4%, but this became higher in South Asian low-income countries, Southeast Asian ASEAN countries, and NIEs in this order, and the highest in Japan, Brunei, Singapore, and Hong Kong with more than 20% (See Figure-10).

(Industrial Sector)

① In the composition of the three kinds of energy, i. e. fossil fuels, electricity, and vegetal fuels, in final energy consumption for industrial use, the share of fossil fuels was increased in place of vegetal fuels in South and Southeast Asian countries, while the share of electricity was increased in place of fossil fuels in the rest of the countries. Meanwhile, in the composition of coal, oil, and gas in the fossil fuels, some countries had substituted gas for oil, while others coal for oil (Figure-11).

② Japan lead the list of energy consumption per capita in the industrial sector followed by NIEs, China, and Malaysia, while Nepal and Bangladesh were the lowest. Among them, Japan and the Philippines had decreased consumption during the period from 1975 and 1987, while the rest had increased it. Meanwhile, China and Viet Nam had large energy consumption per industrial GDP indicating energy inefficiency in their industrial sector agaist GDP in general.

(Transportation Sector)

① The mix of energy sources for final energy consumption in the transportation sector was 89.4% for oil, 9.0% for coal, and 1.6% for electricity indicating that oil was the dominant energy source in most of the countries, and the share of coal had been on the decrease making a shift to oil in China and India.
The total amount of coal consumed in China, however, had been on the increase(See Figure-12).

② In energy consumption per capita in the transportation sector, Brunei was

Fig. 11. Trends in the Composition of the Energy Sources in the Industrial Sector in Asia by Countries

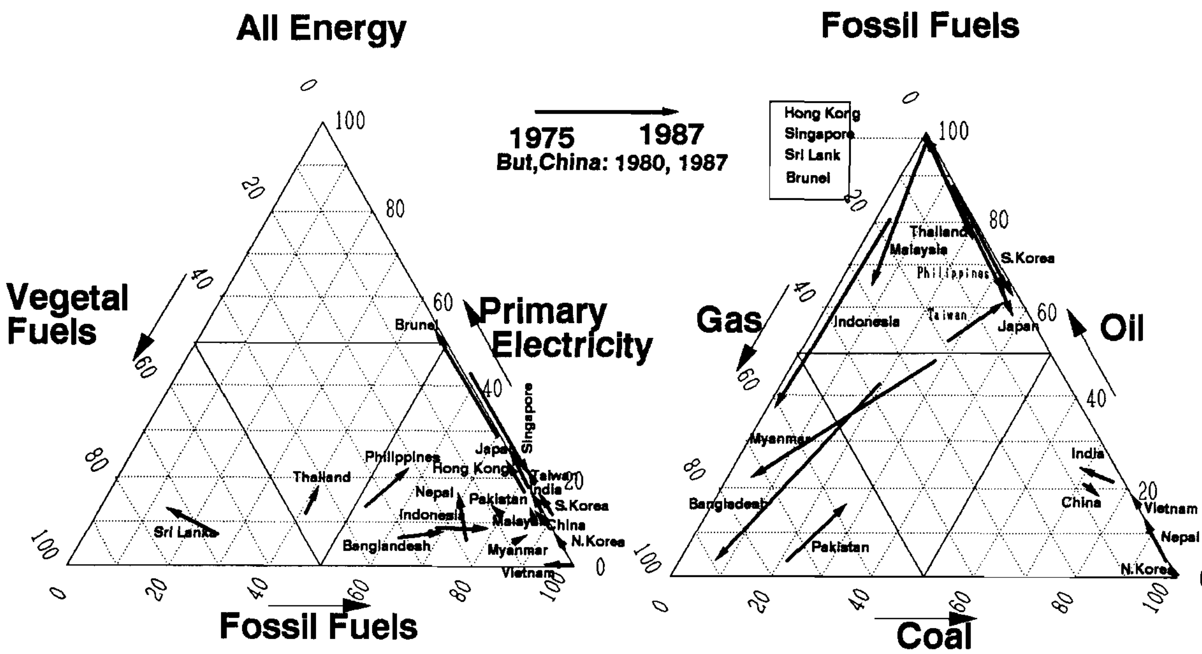
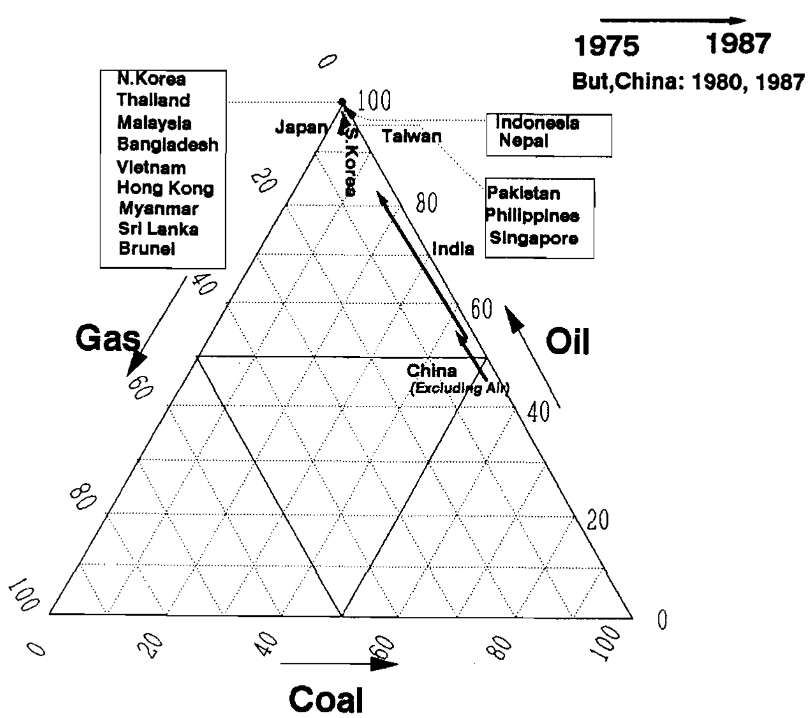


Fig. 12. Trends in the Composition of Fossil Fuels in the Transportaion Sector in Asia



the largest in 1987 followed by Japan, NIEs and ASEAN countries in this order. During the period from 1975 to 1987, South Korea, Taiwan, Thailand, and Brunei, showed the highest growth. Thailand, Malaysia, and Sri Lanka had larger energy consumption per GDP indicating that transportation activities were brisker than other economic activities in these countries.

("Other" Sector)

① In the composition of three energies, i. e. fossil fuels, electricity, and vegetal fuels, in the final energy consumption of the "other" sector, vegetal fuels accounted for more than 50% in most of the South and Southeast Asian countries, but the share of vegetal fuels had been on the decrease and that of fossil fuels or electricity had increased instead. Also, a shift from fossil fuels to electricity was witnessed in Japan and Asian NIEs. Meanwhile, in the composition of three kinds of energy sources, i. e. coal, oil, and gas, among fossil fuels, a shift to oil was witnessed in South Korea and India who had high dependence on coal, and an increase in the share of gas was witnessed in Hong Kong, Malaysia, and other countries with high dependence on oil (See Figure-13).

② In 1987, the energy consumption per capita in the"other" sector was larger in Japan, Brunei, South Korea, and Nepal indicating that it was related to heating demand in winter and air conditioning demand throughout the year as in the case of Brunei. These countries and NIEs showed a substantial increase in consumption from 1975 to 1987, while the other countries almost remained unchanged indicating that energy consumption in the"other" sector consisting mainly of residential use did not increase in developing countries. In the meantime, the energy consumption per GDP was large in South Asian countries, such as Nepal, Viet Nam, Myanmar, etc. becoming smaller in ASEAN countries and NIEs in this order showing the necessity of energy consumption in the " other" sectors consisting mainly of residential uses regardless of the size of GDP.

2) Energy Conversion Sector

(Electricity Generation Sector)

① In the composition of the three energy sources of fossil fuels, nuclear power, and hydraulic and other powers put into electricity generation, the share of fossil fuels had been on the increase in India, Indonesia, Thailand, etc., the share of hydraulic and other powers had been on the increase in Nepal, the

Fig. 13. Trends in the Composition of the Energy Sources in the Other Sector in Asia by Countries

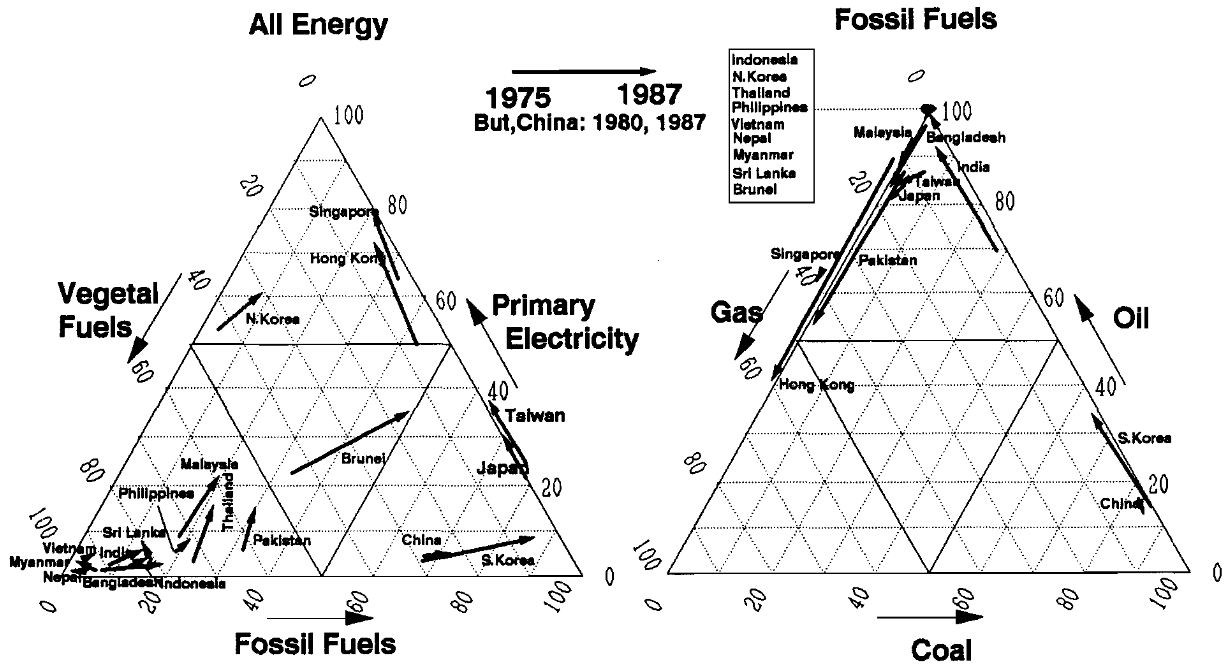
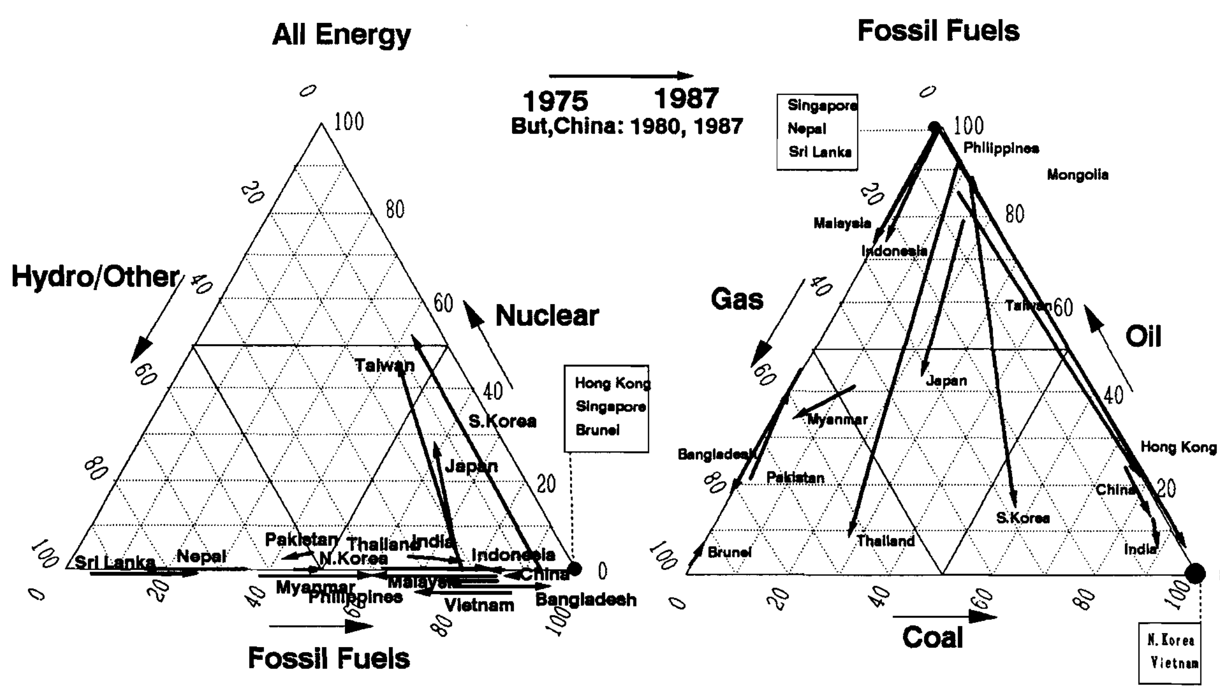


Fig. 14. Trends in the Composition of the Energy Sources in the Electricity Generation Sector in Asia by Countries



Philippines, Viet Nam, Pakistan, etc., and the share of nuclear power had been on the increase in South Korea, Taiwan, and Japan. Meanwhile, in the composition of the three fossil fuels of coal, oil, and gas, some countries had converted oil to gas, while others to coal, and some others to both gas and coal. The share of coal was high in China (1975: 75%, 1987: 85%) and in India (1975: 86%, 1987: 90%), but a shift in the trend toward coal was still observed in both countries (See Figure-14).

② The elecricity generation efficiencies (equivalent to calories generated in real terms which are larger than the gross calories generated) were between 28% and 40% in Asian countries in 1987. Among them Japan was the highest followed by NIEs, ASEAN countries and South Asian countries in this order. The electricity generation efficiency had been improved remarkably in Singapore, China, etc. from 1975 to 1987 (See Figure-15). The gross losses in the electricity generation sector (a total of the in-plant consumption and transmission losses) in these countries were between 10% and 30%, and by country, Japan had the smallest percentage followed by NIEs, ASEAN countries, and South Asian countries as in the same order of the generation efficiency (See Figure-16).

Fig. 15. Electricity Generation Efficiency: Asian Countries

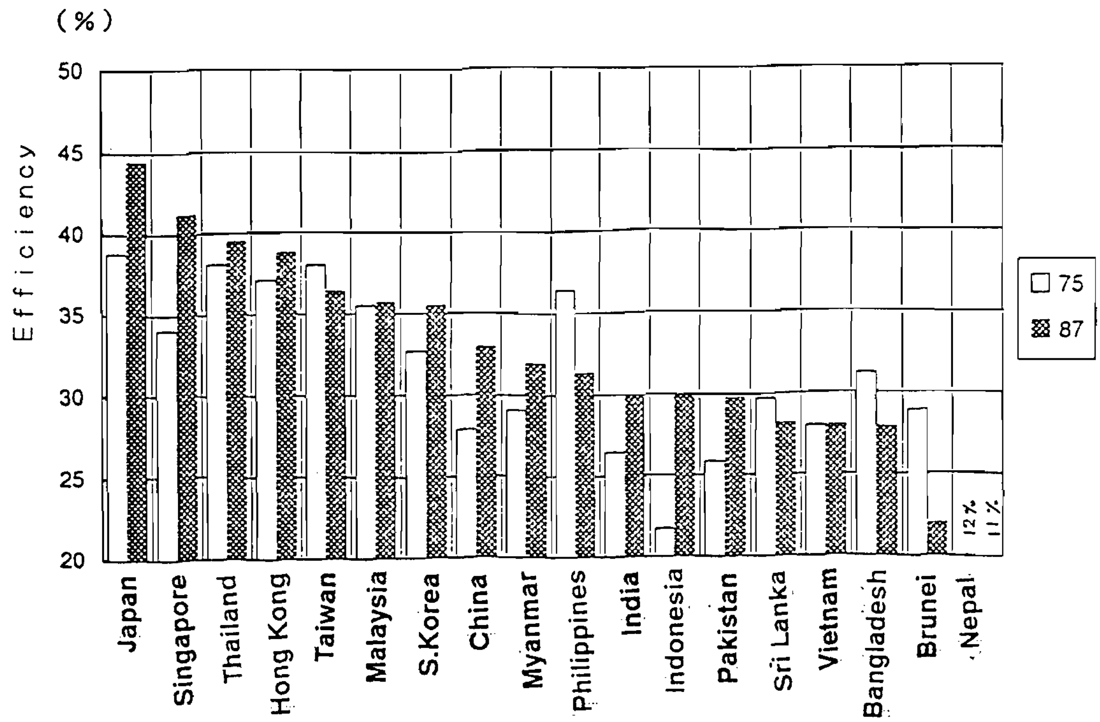
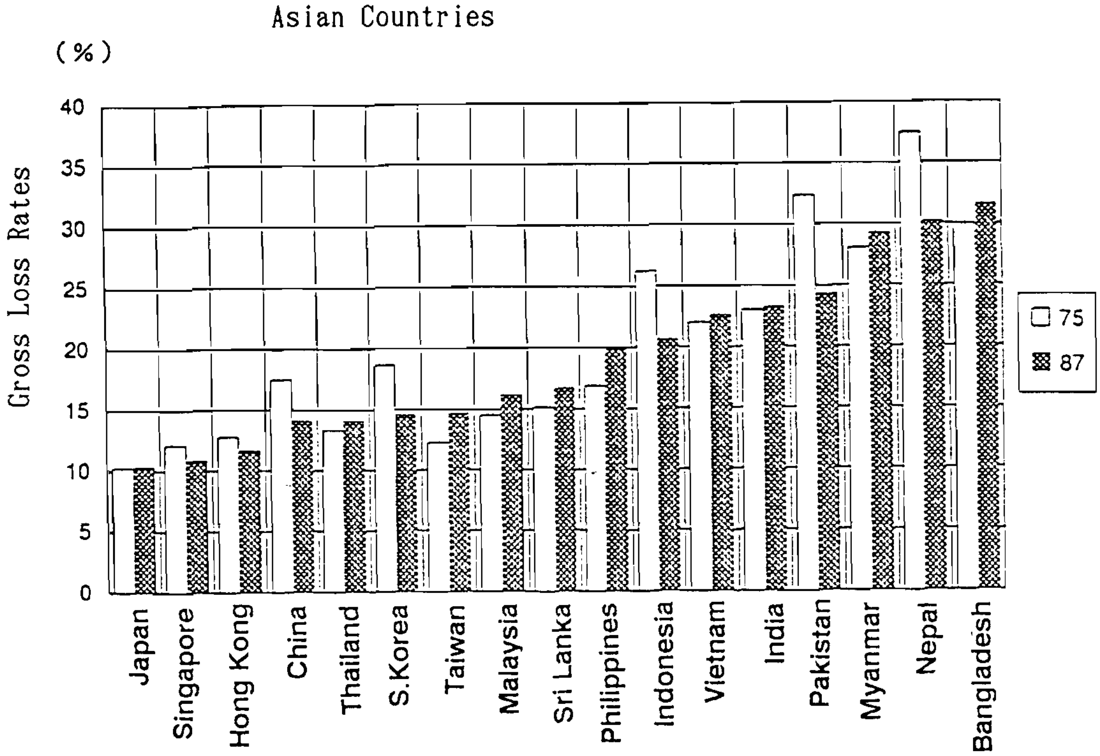


Fig. 16. Gross Losses in Electricity Generation Sector: Asian Countries



3. Air Pollution and Its Measures in Asian Region

(1) The Present Situation of Air Pollution

① Of the 25 Asian countries, the present situation of air pollution including the qualitative one is known only in 13 countries (China, Japan, India, Indonesia, South Korea, Thailand, Pakistan, the Philippines, Malaysia, Hong Kong, Singapore, and Nepal). In these countries, air pollution in urban areas, especially in the metropolitan areas, had been aggravated. The causes of this air pollution are classified into a) northern parts of China (Tung-pei and Hua-pei districts), and the metropolitan areas in South Korea, etc. where heating is needed in winter time, b) the metropolitan areas in Southeast Asian countries (except Singapore), India, and Pakistan where a number of unfixed cars are increasing, c) urban areas in NIEs such as South Korea, Taiwan, Hong Kong, Singapore, etc. where the number of cars is increasing rapidly in addition to the rapid industrial development, d) the metropolitan and other areas in Japan where the number of cars is increasinly offsetting the effect of the regulation on NOx in automobile exhaust gas emission.

② Regarding atmospheric concentration of SO2, cities exceeding a guideline of WHO (40-60 μg/m3), in the atmospheric concentration of SO2 (an average of 5 years from 1980 to 1984) of 14 Asian cities listed by UNEP/WHO, were Sheng-yang Soul, Xian, Beijing, Manila, Canton, Calcutta, Shanghai, Hong Kong, and New Delhi in this order of the magnitude, and cities lower than the guideline were Tokyo, Osaka, Bombei, and Bangkock. A large increase in the SO2 concentration was recorded in Canton, Shanghai, Beijing, and New Delhi. The increase in Canton and Shanghai was considered to be the result the rapid industrial development (See Figure-17).

③ Regarding the atmospheric concentration of NO_2 , of 4 cities in Asia shown by UNEP/WHO. Osaka led the list with 60 μg/m3, followed by Hong Kong with 45 $\mu g/m^3$, Singapore with 40 $\mu g/m^3$, and New Delhi with 33 $\mu g/m^3$ (an average from 1980 to 1987) . Meanwhile, environmental standards for the atmospheric concentration of NO_2 were exceeded in many cities in Japan and Taiwan, and in Hong Kong.

④ Acid rains with pH value between 4% and 5% were frequent all over Japan except Hokkaido, Soul in South Korea, Xi-nan, Chu-nan, and Hua-nan districts in China, and they cast serious problems especially in Guizhou and Sichuan provinces.

(2) Air Pollution Measures

① Envionmentl standards or guidelines for SO_2 are set up in 10 countries in Asia

Fig. 17(1). The SO2 Concentration in Major Cities in Asia -the annual average-

Site: Center of City

(3) **WHO Guideline 40 60 g/m3**

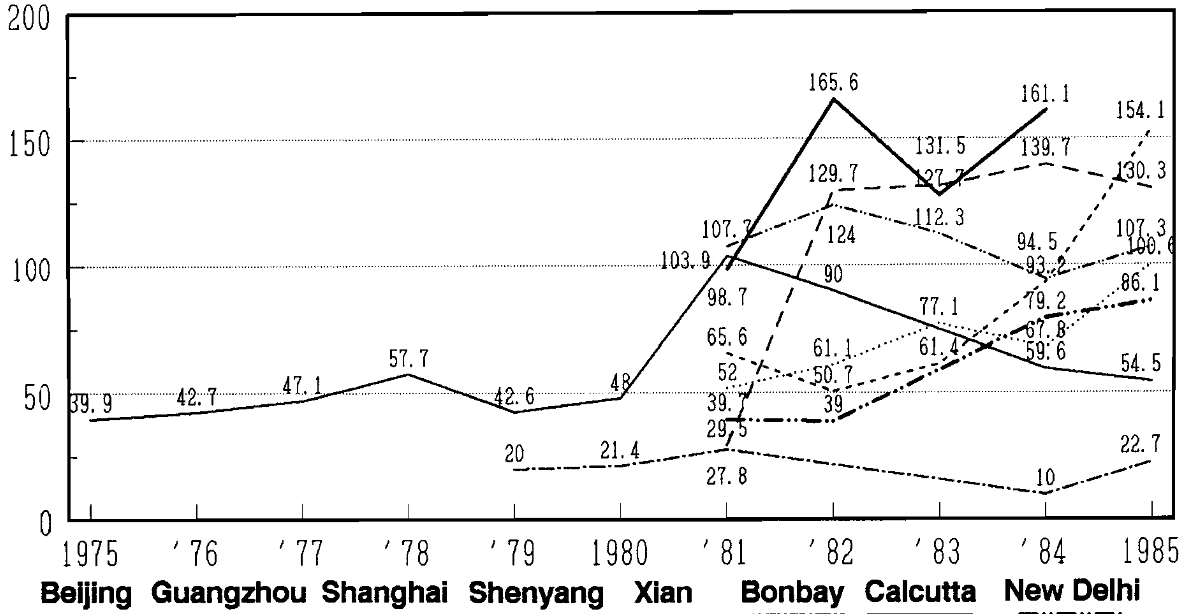
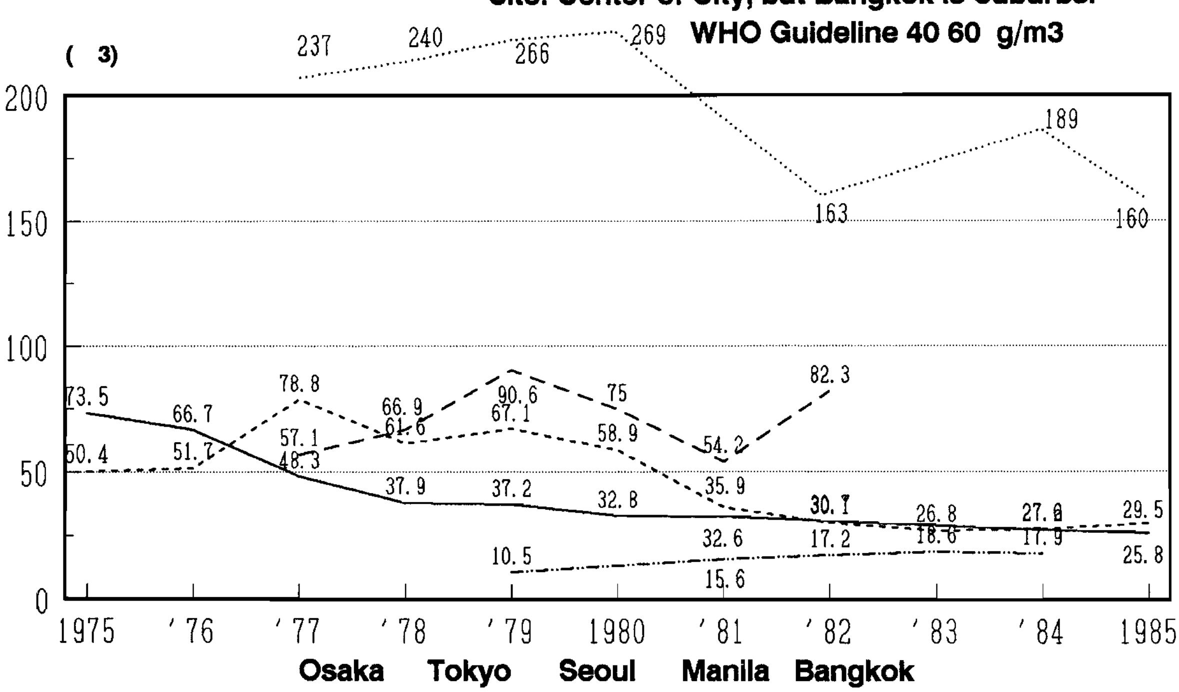


Fig. 17(2). The SO2 Concentration in Major Cities in Asia -the annual average-

Site: Center of City, but Bangkok is Suburbs.

(3) **WHO Guideline 40 60 g/m3**



Source: AIR QUALITY IN SELECTED URBAN AREAS WHO

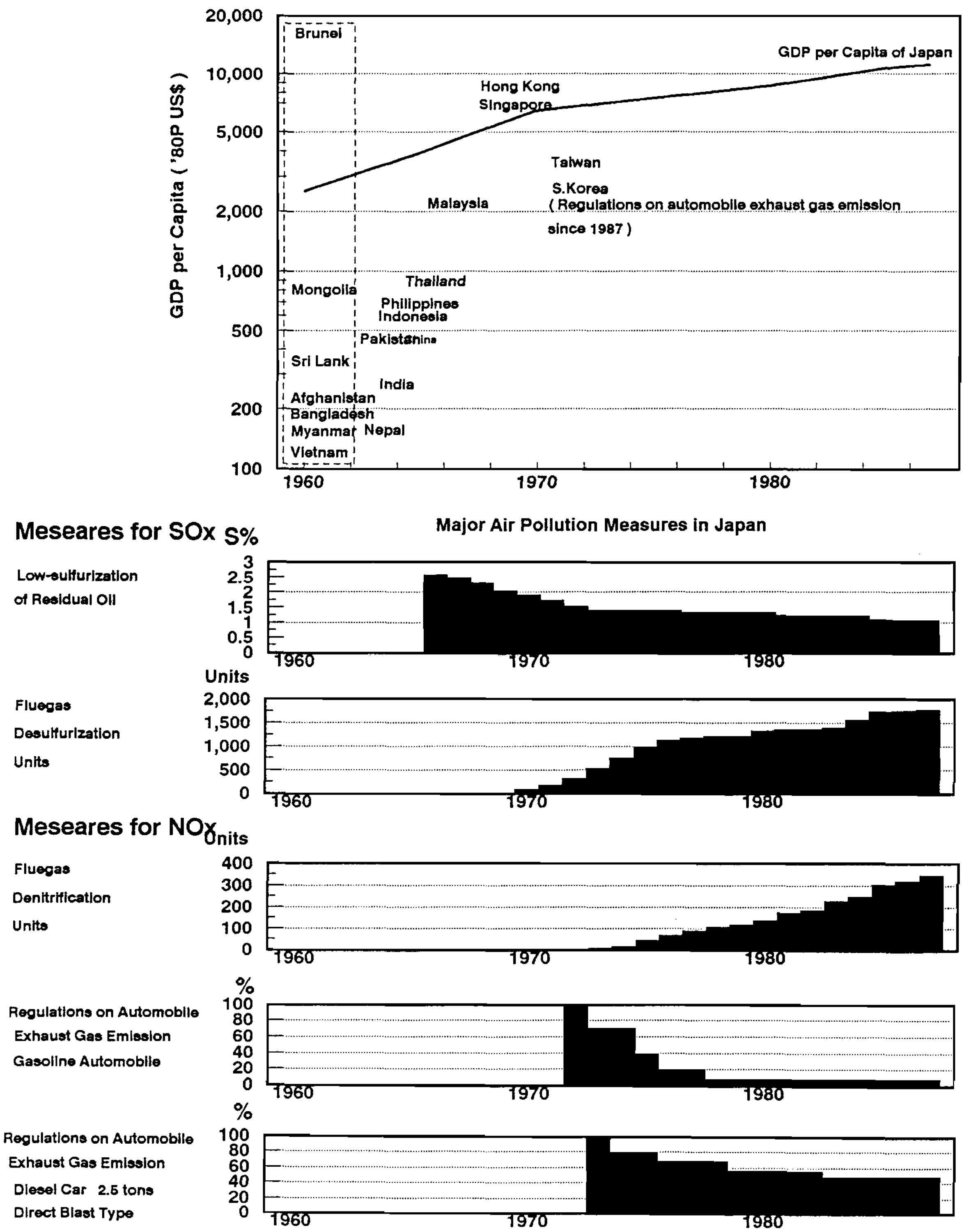
but Seoul, Environment White Report

(China, Japan, India, Indonesia, South Korea, Taiwan, Thailand, the Philippines, Hong Kong, and Singapore), while environmental standards or guidelines for NO_2 are set up in 9 countries (China, Japan, India, Indonesia, South Korea, Taiwan, Thailand, the Phlippines, and Hong Kong).

② Measures to guarantee environmental standards include improvements in the combustion efficiency, coal-washing, and high stacks as found in China. Also, measures for low-sulfurization of fuels are carried out in Japan, South Korea, and Taiwan, but installments of fluegas desulfurization and denitrification units as carried out in Japan are scarcely found out in the other countries.

As for regulations on automobile exhaust gas emission, other than Japan whiel has put regulation into practice since 1973, only South Korea has carried out similar regulation since July of 1987. Thus, in Asia, except Japan, measures for SOx and NOx in a full scale will have to be carried out starting from the present (See Figure-18).

Fig. 18. Comparissons of Major Air Pollution Measures (SOx and NOx) in Japan
the Present Status (around 1987) of Measures in Asian Countries



4. Emission Factors of SOx, NOx, and CO_2

(1) SOx

The amount of the SOx emission resulting from energy consumption was estimated by multiplying the amount of the energy consumption, dividing into 17 kinds of energy consumption sectors and 27 kinds of fuels, by emission factors of SOx corresponding to each kind of the division. Furthermore, the amount of the SOx emission from other sources than energy consumption was estimated from the amount of the emission from smeltering and recovery of sulfuric acid in the non-ferrous metals and sulfuric acid manufacturing industries respectively.

Further, as for Japan, the amount of SOx was estimated based upon the amount of the SOx emission fand in the Environment Agency's " A Comprehensive Study on Air and Environmental Pollutants " plus an estimate from the above-mentioned amount of fuel oil consumption and emission factors regarding the sectors excluded in the study.

① **Emission factors of SOx** In view of the fact that fluegas desulfurization units are scarcely installed in Asian countries except Japan, we carried out our study by applying the emision factors of SOx without fluegas desulfurization units to Asian countries other than Japan. At the same time, this method was applied to the estimate of the amount of the emission in " Without Fluegas Desulfurization Case of Japan. " The results of the estimate is given in Table-6. The emission factor S in the Table indicates sulfur contents of fuels (expressed in %), and since hard coal, brown coal, and petroleum products have different values by consuming countries, we made a review on a country-by-country basis. With respect to fuels other than the above, we reviewed sulfur contents of these fuels in common among the countries and set up the emision factors as follows:

a. **Sulfur contents of fuels** Since sulfur contents of hard coal, brown coal, and main petroleum products vary widely by regions, we made a review on a country-by-country basis, and especially for hard coal, we reviewed the sulfur contents by regions of China and India. The result of the review is given in Figures-19 through -21 and Table-7. The changes in the trends in the sulfur contents are assumed to be none through the period from 1975 to 1987 due to the shortage of the data. Nevertheless, we reviewed the changes in the yearly trend in the sulfur contents of fuels and reflected the result to the emission factors in Japan, South Korea, and Taiwan in which fuel oil low-sulfurization measures are

Table 6(1) Emission factor of SO_X for individual source category and fuel type

＊ As SO_2 equivalent

Fuel / Emission Source Gategory	Goals							Gases		Petroleum products
	Hard Coal (kg/t)	Brown Coal (kg/t)	Coke (kg/t)	Patent Fuel (kg/t)	BKB (kg/t)	BFG (kg/ 10^{10}cal)	COG (kg/ 10^{10}cal)	GWG (kg/ 10^{10}cal)	Natural Gas (kg/ 10^{10}cal)	Crude Oil (kg/t)
Transformation Sector										
Patent Fuel and BKB Plants	0	0								
Coke Ovens	1.37*S		0							
Gas Works	1.55*S		1.77*S			0.001	3.8*S		0.000092	2.0*S
Oil Refineries									0.0092	0.46*S
Electric Generation	19.5*S	19.5*S				0.01	38*S	0.01	0.0092	20.0*S
Non Specified Transformation	15.5*S						38*S	0.01	0.0092	20.0*S
Own Use	15.5*S		17.7*S			0.01	38*S	0.01	0.0092	20.0*S
Industrial Sector										
Iron and Steel	15.5*S					0.01	38*S	0.01	0.0092	20.0*S
Chemical and Petrochemical	15.5*S	15.5*S	17.7*S				38*S	0.01	0.0092	20.0*S
Non-Metallic Minerals	15.5*S	15.5*S	17.7*S				38*S	0.01	0.0092	20.0*S
Others and Non Specified	15.5*S	15.5*S	17.7*S	10.0			38*S	0.01	0.0092	20.0*S
Transport Sector										
Civil Aviation										
Road Transport										
Railways	15.5*S		17.7*S							
Navigation and Others			17.7*S						0.0092	20.0*S
Other Sector										
Residential	12.0*S	12.0*S	17.7*S	10.0	10.0		3.8*S	0.01	0.0092	20.0*S
Agriculture, Commerce etc.	12.0*S	12.0*S	17.7*S				3.8*S	0.01	0.0092	20.0*S

Note 1 : The factors are available only when there is no instellment of fluegas desulfurization.

Note 2 : *S : Sulfur contents of fuels (%)

positively carried out as environmental measures.

Among sulfur contents of coke oven coke, coke oven gas, patent fuel, and BKB, those of coke oven coke and coke oven gas are established so that the sulfur content of hard coal, the material of these fuels, to be reflected referring to " Air Pollution Handbook, Volume of Combustion, edited by National Air Pollution Research Association, Corona Publishing Co., " and the sulfur content of briquette in the Handbook was applied to those of patent fuel and BKB.

Among the sulfur contents of natural gas, gas works gas, blast furnace gas, refinery gas, NGL, and LPG, we referred to " Compilation of Air Pollutant Emission Factors, Volume I, U.S. EPA, 1985 " for that of natural gas. It is assumed that the sulfur contents of gas works gas, blast furnace gas, refinery gas, and NGL are the same as that of natural gas. Further, for LPG, it is set up referring to the above document of U.S. EPA and the Handbook.

Of the sulfur contents of bagasse, fuelwood, charcoal, and other non-commercial fuels, those of bagasse and fuelwood are estimated referring to the data of U.S. EPA (1985), and those of charcoal and the other non-commercial fuels are set up assuming that they are the same as those of bagasse and fuelwood.

b. The rate of atmospheric release of sulfur by combustion Of the sulfur contents of fuels, the rate of the amount to be retained in ash vs. the amount to be released in the atmosphere at the time of combustion and the rate of the amount to be retained in the raw materials or products themselves vs. the amount to be released in the atmosphere are estimated in the following manner.

The rates of atmospheric release of sulfur in hard and brown coals are assumed at 97.5% in the electricity generation sector and 77.5% in the industrial sector except electricity generation industry and industries in the"other" sector based on the data of the U. S. EPA (1985). Further, in the " other" sector, the rate is set up at 60% in view of the low efficiency of the combustion in the sector.

It is assumed that 86% of the sulfur contents of an iron ore (assumed to be 0.03%) are released in the atmosphere based on an assumption that five-sixth of the sulfur in coke oven coke used in the iron & steel industry are to be retained in the products, etc. and the remaining one-sixth are released in the atmosphere.

Table 6(2) Emission factor of SO_x for individual source category and fuel type

* As SO_2 equivalent

Fuel / Emission Source Category	Petroleum Products									
	NGL (kg/t)	Refinery Feed-stocks (kg/t)	Refinery Gas (kg/t)	LPG (kg/t)	Aviation Gasoline (kg/t)	Motor Gasoline (kg/t)	Jet Fuel (kg/t)	Kerosene (kg/t)	Diesel Oil (kg/t)	Residual Oil (kg/t)
Transformation Sector										
Patent Fuel and BKB Plants										
Coke Ovens										
Gas Works			0.0013	0.00136					20.0*S	20.0*S
Oil Refineries	0.013	0.46*S								
Electric Generation	0.013		0.013	0.0136		20.0*S		20.0*S	20.0*S	20.0*S
Non Specified Transformation			0.013	0.0136					20.0*S	20.0*S
Own Use			0.013	0.0136		20.0*S		20.0*S	20.0*S	20.0*S
Industrial Sector										
Iron and Steel				0.0136		20.0*S		20.0*S	20.0*S	20.0*S
Chemical and Petrochemical	0.013		0.013	0.0136		20.0*S		20.0*S	20.0*S	20.0*S
Non-Metallic Minerals			0.013	0.0136		20.0*S		20.0*S	20.0*S	20.0*S
Others and Non Specified			0.013	0.0136		20.0*S		20.0*S	20.0*S	20.0*S
Transport Sector										
Civil Aviation					0.8	20.0*S	3.2		20.0*S	20.0*S
Road Transport				0.0136		20.0*S		20.0*S	20.0*S	20.0*S
Railways						20.0*S			20.0*S	20.0*S
Navigation and Others						20.0*S		20.0*S	20.0*S	20.0*S
Other Sector										
Residential			0.013	0.0136		20.0*S		20.0*S	20.0*S	20.0*S
Agriculture, Commerce etc.			0.013	0.0136		20.0*S		20.0*S	20.0*S	20.0*S

Note 1 : The factors are available only when there is no instellment of fluegas desulfurization.

Note 2 : *S : Sulfur contents of fuels (%)

These emission factors are set up on the basis of the amount of coke oven coke used (one ton of coke oven coke is used for three tons of an iron ore).

In the cement manufacturing process, cement itself absorbs the sulfur and the rate of the absorption is estimated at 75-85%, in order to calculate the emission factors, based on " Trends in Industry and Environment, Japan Institute for Social and Econimic Affairs, August 1989." In this case, the weight of standard coals needed to manufacture one ton of cement are estimated at 126 kilograms in Japan, 165 kilograms in NIEs, and 195 kilograms in the other Asian countries, and the rates of SOx absorption at 85%, 80%, and 75% respectively.

c. Unidentified amount of consumption in the energy transformation sector Since the whole or a part of the amount used for the energy transformation in coke ovens, gas works, and oil refineries in the energy transformation sector cannot be identified, they are estimated in the following manner.

In the case of coke ovens, in which coke oven gas is used as an energy source, it is estimated based on the data from the Japanese iron & ore industry that 18% of the generated coke oven gas be used in the heating of the coke ovens.

In the case of gas works, it is estimated that, in addition to gas oil and fuel oil, 10% of the raw materials be consumed as fuels for heating. One percent of the input of natural gas is, however, assumed to be used for heating.

In the oil refineries, since fuels for use in boilers and oil furnaces are counted in the consumption of the refinery in the energy transformation sector, then it is assumed that 2.3% of the sulfur contained in the crude oil and feedstocks are emitted through fluid catalytic cracking other than the above (See "Sulfur Dioxide Emmissions from Oil Refineries and Combustion of Oil Products in Western Europe (1989), Report No. 2/91, CONCAWE, April 1991").

② The amount of the SO_2 emission in non-ferrous metal refining and sulfuric acid production A large amount of SO_2 is emitted from the smeltering process of non-ferrous metals such as bronze, zinc, etc. In Japan, these exhausted gasses from the smeltering were released into the atmosphere before, but most of them are recovered now to produce sulfuric acid. They are, however, still released into the atmosphere considerably in the other countries. Meanwhile, sulfuric acid is also

Table 6(3) Emission factor of SO_x for individual source category and fuel type

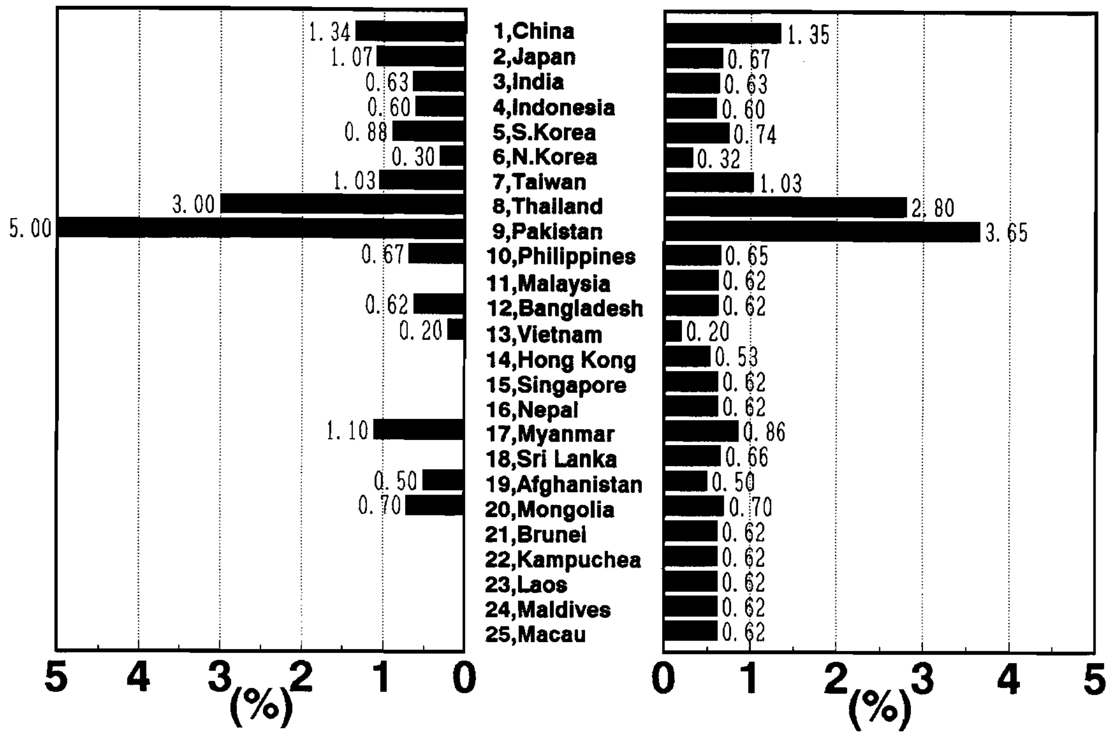
* As SO_2 equivalent

Emission Source Category \ Fuel	Petroleum Products: Naphtha (kg/t)	Petroleum Products: Others (kg/t)	Vegetal Fuels: Bagasse (kg/toe)	Vegetal Fuels: Fuel-Wood (kg/toe)	Vegetal Fuels: Charcoal (kg/toe)	Vegetal Fuels: Other Non-Commercial (kg/toe)
Transformation Sector						
Patent Fuel and BKB Plants						
Coke Ovens						
Gas Works	0.1					
Oil Refineries		1.0				
Electric Generation	1.0	1.0				1.0
Non Specified Transformation		1.0		0.86		1.0
Own Use	1.0	1.0				
Industrial Sector						
Iron and Steel	1.0			0.86		
Chemical and Petrochemical	1.0	1.0				
Non-Metallic Minerals		1.0				
Others and Non Specified	1.0	1.0	1.1	0.86		1.0
Transport Sector						
Civil Aviation						
Road Transport						
Railways						
Navigation and Others						
Other Sector						
Residential				0.86	1.0	1.0
Agriculture, Commerce etc.	1.0		1.1			

Note 1 : The factors are available only when there is no instellment of fluegas desulfurization.

Note 2 : *S : Sulfur contents of fuels (%)

Table 19. Sulfur Contents of Coal in Asian Countries



Remarks

(1) Sulfur contents on a production basis

1) Data collected through our field trips: China, India, South Korea, and Thailand
2) Quoted from ESCAP data: Indonesia, North Korea, Pakistan, Myanmar, Afghanistan, and Mongolia
3) Survey data in Japan: the Philippines and Viet Nam
4) " Coal Mining Yeanbook, the Tex Report LTD. ", " Coal and Technology for Utilization, National Institute of Resources, Science and Technology Agency " : Japan.
5) The average of India, Indonesia, and the Philippines at 0.62% applied to unavailable data: Bangladesh

(2) Sulfur contents on a consumption basis

1) Sulfur contents on a consumption basis are calculated by weighted average of domestic production and imports.
2) Sulfur contents of imported coal " Coal Mining Yearbook, the Tex Report LTD. ", " Report on ASEAN Coal Producing Countries, the Institute of Energy Economics Japan ", but 0.62% (actual level of Japan in 1985) is applied to countries where data on sulfur contents is not available.
3) Sulfur contents include brown coal in countries where brown coal is used. The sulfur content of brown coal is set up at 1.5 times hard coal in Japan, India, North Korea, the Philippines, and Singapore, because of the lack of data in these countries.
4) Low-sulfurization (on a consumption basis) is considered in Japan, South Korea, and Taiwan.

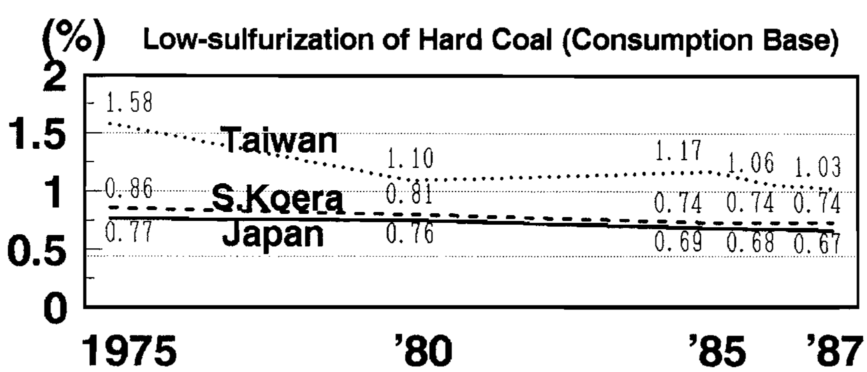
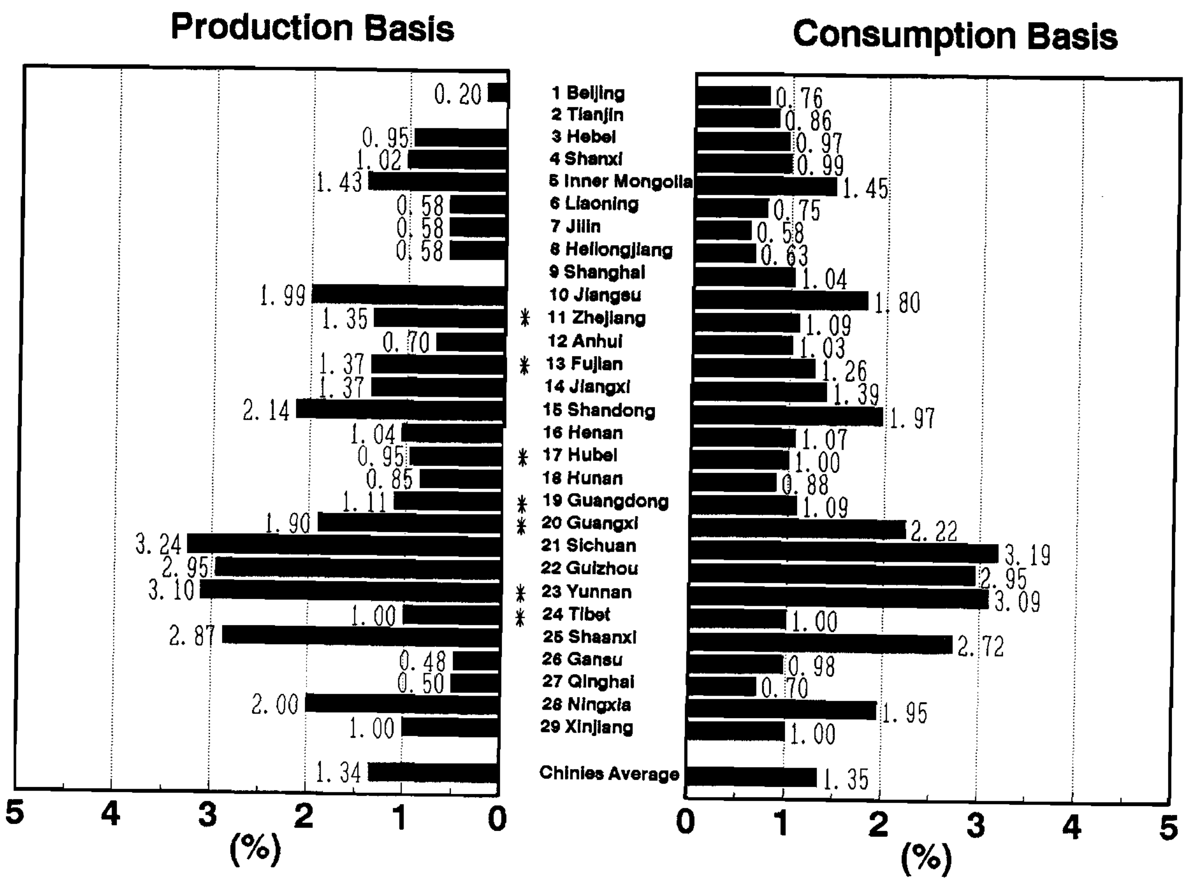


Fig. 20. Sulfur Contents of Coal in China by Provice



Remarks:

(1) Sulfur content on a production basis

1) Centrally-distributed coal

The average sulfur content of centrally-distributed coal by Province is established by calculating the weighted average of the average sulfur content of centrally-distributed coal by Province obtained at the consultation (made in February 1990) of Chinese Coal Distribution Corporation and the sulfur content of centrally-distributed coal by coal mines and production quantities of coal by coal mines listed in " Handbook on Industrial Enterprises, ed. Beijing Academic Society for Environmental Science, 1990. "

2) Local coal

Data obtained at the above consultation, and 1.0% for Shanxi Province and 1.9% for Neimenggu are set up based on the Handbook. Though we have information at the consultation that the sulfur content of local coal is higher than those of centrally-distributed coal in the other Provinces, the same sulfur level of centrally-distributed coal is applied to local coal because the details are not available. Furthermore, the sulfur level of the Provinces (with asterisks) with no centrally-distributed coal mines is established by the arithmetic mean of those of the neighboring Provinces.

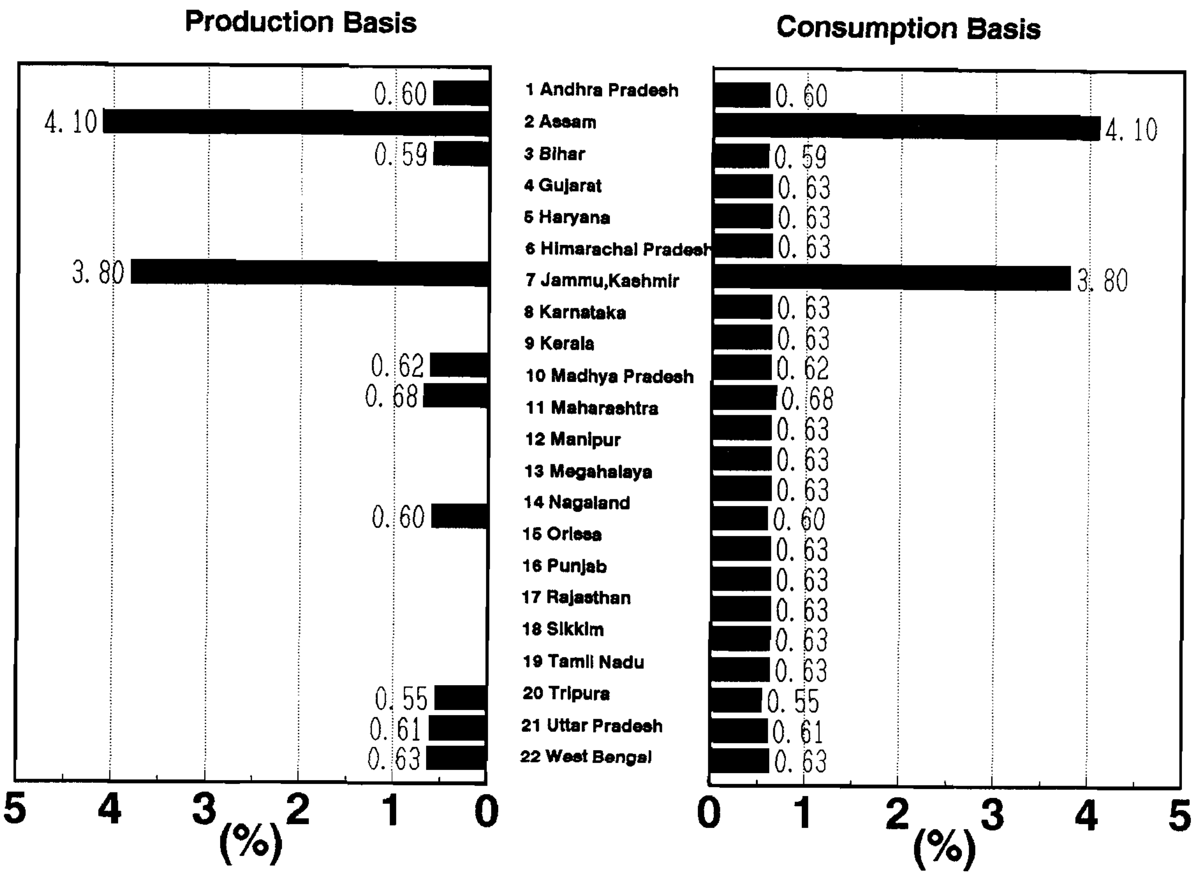
3) Total

The sulfur content on a production basis is calculated by the weighted average of the quantities of production of centrally-distributed coal and local coal.

(2) Sulfur content on a consumption basis

The sulfur content on a consumption basis is calculated based on the quantities of centrally-distributed coal transferred between Provinces recorded in " China Coal Statitistical Yearbook 1986, " etc. and on the assumption that there was no local coal transferred between Provinces.

Fig. 21. Sulfur Contents of Coal in India by States



Remarks:
(1) On a production basis
Arithmetic mean by States of sulfur contents by coal mines listed in " Mukherjee et al, Fuel Science and Technology Vol. 1, No. 1, July '82." But, brown coals, accounting for 4.9% of the total, are not included due to lack of data on the sulfur levels.
(2) On a consumption basis
Since the production quantity of the high sulfur coals in Assam and Jammu & Kashmir is small, it is assumed that no transfer is made to the other States, and since a variation of sulfur levels in the other States is small, the national average in India is applied to the States having no coal production.

Table 7. Sulfur Contents(Average) "S" of Petroleum Products and the Assumptions: Asian Countries

(Unit : wt %)

Countries	Motor Gasoline	Kerosene	Gas/Diesel Oil			Residual Fuel Oil
			Mobile	Industry	Navigation	
1,China	0.120 *	0.032 *	0.16 *	0.40 *	1.20 *	1.50 *
2,Japan	0.004	0.004	0.40	0.40	0.40	1.09
3,India	0.180 *	0.200 *	0.80 *	1.44 *	1.44 *	3.20 **
4,Indonesia	0.005	0.160 *	0.50	0.50	0.50	2.80 *
5,S.Korea	0.005	0.012 *	0.40	0.40	0.40	2.64
6,N.Korea	0.120 **	0.032 **	0.16 **	0.40 **	1.20 **	1.50 **
7,Taiwan	0.125	0.080 *	0.50	1.00	1.00	1.70
8,Thailand	0.035	0.020	0.66	0.50	—	2.92
9,Pakistan	0.001	0.160 *	1.00	1.00	1.00	3.20 **
10,Phillippines	0.035	0.020 **	1.00	1.00	1.00	3.20 *
11,Malaysia	0.140	0.160 *	0.96	0.96	0.96	3.20 *
12,Bangladesh	0.180 **	0.200 **	0.80 **	1.44 **	1.44 **	3.20 **
13,Vietnam	0.120 **	0.032 **	0.16 **	0.40 **	1.20 **	1.50 **
14,Hong Kong	0.020	0.080 **	0.50	0.50	0.50	2.20 **
15,Singapore	0.140	0.020 **	0.46	0.46	0.46	1.60 *
16,Nepal	0.180 **	0.200 **	0.80 **	1.44 **	1.44 **	3.20 **
17,Myanmar	0.180 **	0.200 **	0.80 **	1.44 **	1.44 **	3.20 **
18,Sri Lanka	0.180 **	0.200 **	0.80 **	1.44 **	1.44 **	3.20 **
19,Afganistan	0.180 **	0.200 **	0.80 **	1.44 **	1.44 **	3.20 **
20,Mongolia	0.120 **	0.032 **	0.16 **	0.40 **	1.20 **	1.50 **
21,Brunei	0.005 **	0.160 **	0.50 **	0.50 **	0.50 **	2.80 **
22,Kampuchea	0.120 **	0.032 **	0.16 **	0.40 **	1.20 **	1.50 **
23,Laos	0.120 **	0.200 **	0.80 **	0.40 **	1.20 **	1.50 **
24,Moldives	0.180 **	0.200 **	0.80 **	1.44 **	1.44 **	3.20 **
25,Macau	0.020 **	0.032 **	0.50 **	0.50 **	0.50 **	2.20 **

Remarks:

Thailand ; "Imports and Exports of Petroleum Products in the Asian/Pacific Region : Present Siturations and Potentials"

Other Countries ; "Current and future Gasoline and Diesel Fuel Quality in the Eastern Hemishere, Product engineering Department Caltex Petroleum Corporation R. J. Organ, Nisseki Review"

However, 0.04 and 0.16 are applied to aviation gasoline and jet fuels respectively, referring to the specifications in Taiwan, Japan, and South Korea, because no data is available for these products.

* : Specifications are available, but the actual data is not available. Eighty percent of the specification figure is applied referring to the rate of the actual data against the specification.

**: The values in similar countries are applied. Indian data applied to (Afghanistan, Bangladesh, Burma, Sri Lanka, Maldives, Nepal, and Laos), China to (North Korea, Mongolia, Vietnam, Laos, Cambodia, and Macau), Taiwan to (Hong Kong), Hong Kong to (Macau), the Philippines to (Indonesia and Pakistan), and Thailand to (the Philippines andSingapore). The average sulfur level in 1986 and 1987 is applied to fuel oils of Hong Kong and Macau. The sulfur levels of fuel oils in Japan, South Korea and Taiwan and gas oil in South Korea are those in 1987, and those in the other years are listed in a different table.

produced from the sulfuric ore or SO_2 from the combustion of sulfur, and around 2 to 5% of the sulfur are emitted depending on processess without turning into sulfuric acid.

These amounts of SO_2 emission are estimated based on the production quantities of bronze, zinc, lead, and tin in the United Nation's statistics by country and the production quantity of sulfuric acid in the Sulfuric Acid Notebook published by Japan Sulfuric Acid Association.

③ The amount of the SOx emission in Japan Low sulfurization of fuels has been implemented since the end of the 1960's in Japan as a measure for the reduction of the emission of SOx, and at the same time large-scale fluegas desulfurization units have been installed in generation and other plants since around 1970. Meanwhile, the amount of the SOx emission has been monitored for larger emission sources of the stationary sources by the Environment Agency as " Comprehensive Survey of Air Pollutants."

Thus, the total amount of SOx in Japan is estimated by adding the estimated amount of the smaller stationary emission sources which are not included in the Survey and that of the mobile sources to the amount of the SOx emission of the Comprehensive Survey. The amount of the SOx emission of the smaller stationary sources is estimated by multiplying the uncaptured amount of fuel consumption in the Comprehensive Survey, comparing that with the amount in the "other" sector mainly consisted of residential uses in the energy statistics, by the emission factor described in the above ①. Similarly, the amount of the emission from mobile sources is estimated by the amount of fuel consumption and the emission factor described in the above ①.

(2) NOx

The amount of the nitric oxides (NOx) emission resulted from energy consumption is estimated by multiplying the amount of energy consumption mentioned in the above 3, divided into 17 sectors of energy consumption and 27 kinds of fuels, by the NOx emission factors (equivalent to NO_2). As for Japan, the amount of the NOx emission is estimated based on the amount of the NOx emission in JEA's " A Comprehensive Survey of Air Pollutants, ", and to this amount, the amount of emissions from part of the stationary sources that is not included in the above Survey and from the mobile sources estimated separately is added to get the total.

Table 8(1) Emission factor of NO_x for individual source category and fuel type

Emission Source Category \ Fuel	Goals							Gases		Petroleum products
	Hard Coal (kg/t)	Brown Coal (kg/t)	Coke (kg/t)	Patent Fuel (kg/t)	BKB (kg/t)	BFG (kg/ 10^{10}cal)	COG (kg/ 10^{10}cal)	GWG (kg/ 10^{10}cal)	Natural Gas (kg/ 10^{10}cal)	Crude Oil (kg/t)
Transformation Sector										
Patent Fuel and BKB Plants	0	0								
Coke Ovens	1.00		0							
Gas Works	0.75		0.90			0.031	0.229		0.0224	2.19
Oil Refineries									0	0.24
Electric Generation	9.95	8.46				0.44	3.26	0.44	4.40	7.24
Non Specified Transformation	9.95						3.26	0.44	4.40	7.24
Own Use	7.50		9.00			0.31	2.29	0.31	2.24	5.09
Industrial Sector										
Iron and Steel	7.50		2.50			3.18	5.89	3.18	2.24	5.09
Chemical and Petrochemical	7.50	6.38	9.00				2.29	0.31	2.24	5.09
Non-Metallic Minerals	7.50	6.38	9.00				2.29	0.31	2.24	5.09
Others and Non Specified	7.50	6.38	9.00	7.50			2.29	0.31	2.24	5.09
Transport Sector										
Civil Aviation										
Road Transport										
Railways	7.50		9.00							
Navigation and Others			9.00						2.24	5.09
Other Sector										
Residential	1.88	1.60	2.25	1.88	1.88		1.60	0.22	1.57	1.70
Agriculture, Commerce etc.	3.75	3.19	4.50				1.60	0.22	1.57	3.05

Note : The factors are available when there are no combustion technology for NO_x emission control, instellment of fluegas denitrification and regulations on the automobile exhaust gas emission.

① **Emission factors of NOx** In Asian countries other than Japan, improvements in the combustion efficiency, installments of fluegas denitrogen units, regulations of the automobile exhaust gas emissions as measures for the limitation of NOx emissions have scarcely been implemented (In thermal power plants in South Korea and Taiwan, however, the combustion efficiency is being improved. And the regulation on the automobile exhaust gas has been enforced in Korea since July 1987). Based on these circumstances, a review was made by applying emmission factors of NOx without environmental measures to Asian countries except Japan (However, the NOx emission factor considering the improvement in the combustion efficiency is applied to fuel oil burning thermal power plants in Korea and Taiwan). This review was based on the cases without environmental measures in the information described in such documents as " Survey on Emission Factors of Air Pollutants at Stationary Combustion Facilities, Japan Heat Energy technology Association, March 1978 " by JEA, " Survey on Air Pollutant Emission Factors (Stationary Sources), Bureau of Environmental Protection, Tokyo Metropolitan Government, August 1973, " and " Compilation of Air Pollutant Emision Factors, Volume 1, U. S. EPA, 1985. " The result of the review is shown in Table-8, and the outline of the procedures of determining emission factors is as follows:

a. **Energy Transformation sector** With respect to coke ovens, NOx emission factor per calories from the data of JEA are converted into the NOx emission factors per input amount of hard coal utilizing " Air Pollution Handbook, Volume of Combustion, National Air Pollution Research Association, Corona Publishing Co. "

As for gas works, the NOx emission factor per input of feedstock naphtha in gas producing ovens is set up based on the data of JEA, and the emission factor of crude oil is assumed at 1.5 times larger than that of naphtha. Since the use of coal at gas works in Asia is considered to be for horizontal ovens, it is assumed that the 10% of coal and 1% of natural gas input to the gas works are for use in heating. The emission factors for industrial boilers are applied to the input amount of gas oil and fuel oil assuming that these oils are entirely used as fuels.

In oil refining, as fuels for use in heating are counted as refinery fuels, emission factors per the input of crude oil and feedstocks to fluid catalytic cracking units are set up referring to the data of U.S. EPA.

In the electricity generation, the emission factor of fuel oil is established at

Table 8(2) Emission factor of NO_x for individual source category and fuel type

Emission Source Category \ Fuel	Petroleum Products									
	NGL (kg/t)	Refinery Feed-stocks (kg/t)	Refinery Gas (kg/t)	LPG (kg/t)	Aviation Gasoline (kg/t)	Motor Gasoline (kg/t)	Jet Fuel (kg/t)	Kerosene (kg/t)	Diesel Oil (kg/t)	Residual Oil (kg/t)
Transformation Sector										
Patent Fuel and BKB Plants										
Coke Ovens										
Gas Works			0.053	0.263					9.62	5.84
Oil Refineries	0	0.24								
Electric Generation	6.20		0.75	3.74		16.71		21.23	27.37	10.00
Non Specified Transformation			0.75	3.74					27.37	10.00
Own Use			0.53	2.63		16.71		7.46	9.62	5.84
Industrial Sector										
Iron and Steel				2.63		16.71		7.46	9.62	5.84
Chemical and Petrochemical	2.52		0.53	2.63		16.71		7.46	9.62	5.84
Non-Metallic Minerals			0.53	2.63		16.71		7.46	9.62	5.84
Others and Non Specified			0.53	2.63		16.71		7.46	9.62	5.84
Transport Sector										
Civil Aviation					10.5	16.71	10.5		54.13	54.13
Road Transport				20.3		31.7		27.4	27.4	27.40
Railways						16.71			54.13	54.13
Navigation and Others						16.71		54.13	54.13	54.13
Other Sector										
Residential			0.18	0.88		16.71		2.49	3.21	1.95
Agriculture, Commerce etc.			0.32	1.58		16.71		4.48	5.77	3.50

Note : The factors are available when there are no combustion technology for NO_x emission control, instellment of fluegas denitrification and regulations on the automobile exhaust gas emission.

10.0 kg/t, referring to the data of Tokyo Metropolitan Government, JEA, and U. S. EPA, taking nitrogen contents of oil and yet unrealized improvements in the combustion efficiency into consideration. Nevertheless, the emission factor of 6.45 kg/t is set up for South Korea and Taiwn assuming that the improvement in the combustion efficiency will be realized in view of their emission standards. Those of kerosine and gas oil are set up referring to the data for gas turbines and diesel engines prerared by JEA. The value of Tokyo Metropolitan Government is adopted for the emission factor for hard coal, and 85% of that is applied for brown coal. Those for natural gas and NGL are set up referring to the data made by the U. S. EPA.

As for domestic (in-plant) consumption, the emission factors for fuels are established by fuels referring to the data made by JEA, Tokyo Metropolitan Government, and the U. S. EPA.

b. The industrial sector As a variety of combustion facilities are utilized in the industrial sector, the emission factors are established only for two types of indutries, viz. the iron & steel industry and industries other than the iron & steel industry.

For coke ovens, which have the largest emissions of NOx in the iron & steel industry, the emission factor per amount of coke consumed is used referring to the emission factor in the data made by JEA, taking into consideration a close corelation between the output of iron and the amount of coke consumed. For the other fuels for heating, as blast furnace gas and coke oven gas are much used in the industry, the emission factor for the furnace for use in steel rolling is set up representing these gases based on the data of JEA. For the other fuels, the emission factor of industrial boilers is applied.

For the industries other than iron & steel industry, as in the domestic consumption in the energy transformation sector, the emission factor of industrial boilers is applied based on the data of JEA, Tokyo Metropolitan Government, and U. S. EPA.

c. The transportation sector As for aviation, the emission factor includes the emmissions during take-off, landing, and flight ,and the emission factor of gas turbines from the data made by JEA is applied.

The road transportation consists of vehicles fueled by gasoline, diesel oil, and

Table 8(3) Emission factor of NO_x for individual source category and fuel type

Fuel / Emission Source Category	Petroleum Products		Vegetal Fuels			
	Naphtha (kg/t)	Others (kg/t)	Bagasse (kg/toe)	Fuel-Wood (kg/toe)	Charcoal (kg/toe)	Other Non-Commercial (kg/toe)
Transformation Sector						
Patent Fuel and BKB Plants						
Coke Ovens						
Gas Works	1.46					
Oil Refineries		0				
Electric Generation	16.00	10.00				6.00
Non Specified Transformation		10.00		6.00		6.00
Own Use	7.34	5.84				
Industrial Sector						
Iron and Steel	7.34			6.00		
Chemical and Petrochemical	0	5.84				
Non-Metallic Minerals		5.84				
Others and Non Specified	7.34	5.84	3.33	6.00		6.00
Transport Sector						
Civil Aviation						
Road Transport						
Railways						
Navigation and Others						
Other Sector						
Residential				6.00	6.00	6.00
Agriculture, Commerce etc.	4.40		3.33			

Note : The factors are available when there are no combustion technology for NO_x emission control, instellment of fluegas denitrification and regulations on the automobile exhaust gas emission.

LPG, and the emission factors per volume of fuel consumption are established from the amount of the NOx emission per kilometer of car mileage by kinds of vehicles in " Survey on Air Pollutant Emission Factors (Mobile sources), Bureau of Environmental Protection, Tokyo Metropolitan Government, August 1973, " taking the vehicle fuel efficiency into consideration.

For railroads and vessels, the emission factor of the main diesel engine in " Report on Survey of Estimation Methods for Soot from Vessels, Research Group on Vessel Soot Problems, June 1985 " is applied.

d. " The other" sector The emission factor of " the other " sector, consisting of agriculture, commercial, public, and residential uses, is set up referring to that of commercial and residential boilers of the U. S. EPA.

② Emissions of NOx in Japan In Japan, installations of fluegas desulfurization units for stationary emission sources and automobile exhaust gas regulations on mobile sources have been implemented since 1973 as measures for lowering the NOx emission. In the meantime, like SOx, a Comprehensive Survey on the NOx emission has been made on the facilities larger than the specified scale among the stationary emission sources by JEA.

Thus, the NOx emission from stationary sources is estimated in the same manner as SOx based on the result of the Comprehensive Survey. For the road tranportation in the mobile sources, the emission factor per volume of fuel consumption in the period between 1980 and 1987 is established based on the data of " Report on the Survey of Automobile Traffic and Auto-exhaust Emission in Tokyo, Bureau of Environment Protection, Tokyo Metropolitan Government, February 1982, " which is the result of the survey based on the effect of the vehicle exhaust gas emission regulations, and other data, and for 1975, the emission factor is established taking into consideration the NOx emission factor for unregulated cars in 1973 and the regulations of 1973 through 1975 on the registered cars and substitutions of new cars for these cars. For aviation, railroads, and vessels, the unregulated emission factors are applied.

(3) CO_2

The amount of carbon dioxide (CO_2) emission resulting from the energy consumption is estimated by multiplying the amount of fuel consumption, divided consumption into

17 sub-sectors and 27 kinds of fuels, by the CO_2 emission factor corresponding to each sector and kind. Furthermore, other than these, the amount of the CO_2 emmission resulting from cement production is estimated by multiplying the output of cement by the emission factor.

In the estimate of the CO_2 emission based on the energy consumption, it is necessary to determine the CO_2 emission factor of each fossil fuel. So, the method of calculating the CO_2 emission factor will be discussed here. The emission factors calculated in this study are listed in Table-9.

① **Basic idea behind the calculation** The amount of the CO_2 emission is determined by the amount of carbon elements contained in the fossil fuels, which is obtained through element analysis of coal, oil, and natural gas. If there is no unburnt carbon, the amount of CO_2 generated from 1 kg of each fossil fuel is equal to the carbon element quantity converted to kilograms of carbon. The amount of the emission per 1 ton of oil equivalent (10^7 kcal) is obtained by dividing the quantity of carbon elements by calories. The higher the rate of hydrogen (H_2) in fuels, the less CO_2 is emitted. In comparing of the emission rates, coal emits 100%, oil 84%, and natural gas 58%.

In order to calculate the emission factor, it is first necessary to decide whether it should be calculated base on the respective units of fuels or on calories. If it is calculated on a calorie basis, it is necessary to decide whether it is high or low calorie . More precisely, unburnt carbon should also be considered in the calculation, but it is generally neglected because it is not so large an amount. The emission factor of CO_2 could be obtained if these assumptions are fixed and the integrated data such as the carbon element, calories, and specific gravities of the fuels concerned can be collected.

② **The CO_2 emission factor of petroleum products** Based on the information on the relation between the distribution of hydrocarbons in the respective fractions of crude oil and the carbon numbers, and the composition of the respective fractions of crude oil by types of hydrocarbons, the composition of hydrocarbons in the respective petroleum products is estimated, and the rate of the composition of carbon elements in the respective petroleum products is calculated according to that data. As this calculation is based on the data in the magnetic tapes of IEA (International Energy Agency) in which the respective units of fuel are used, the CO_2 emission factors per ton for petroleum products are calculated. If an integrated unit is used, the ratio of the composition of carbon elements becomes exactly the CO_2 emission factor.

③ **The emission factos of coal and gas** As the emission factor for hard coal, the value of 23.8(23.7-23.9)kg-C/GJ, which was established by a study of Oak Ridge Associated Universities, Inc. of the United States (a national research institute), is adopted and used by converting it to 1.065-C/TOE on a real calorie basis (See " Marland, G. ; The Impact of Synthetic Fuels on Carbon Dioxide Emissions, Carbon Dioxide Review, pp 406-410, 1982, Oxford University Press, New York "). The value of 1.115T-C/TOE converted from 25.3kg-C/GJ is used for the emission factor for brown coal. In case of coal, as the carbon content, water content, and ash content differ widely by districts of production, so the emission factors per respective fuel unit differ by districts of production. As there are, however, some constant relations between carbon content and calories, the emission factor per ton of oil equivalent is used in this report.

Though no information is available for patent fuel, the value of 1.065-T/TOE of hard coal is applied to it, taking the recent improvement in the quality of coal into consideration. Also no information is available for BKB, charcoal, and peat, but the value of 1.115T-C/TOE of brown coal is applied to them. As for coke, taking stabilization of the quality by a kind of processing into consideration, the emission factor of 0.868T-C/ton is established according to the data on carbon contents of 0.868.

For natural gas, the emission factor of 0.631×10^{-4}g-C/cal, which is converted from 13.85(13.5-14.2)kg-C/GJ as estimated on a real calorie basis by Oak Ridge Associated Universities, Inc. in the United States is used. The emission factor of gas works gas is set up at 0.697×10^{-4}g-C/cal based on the data on carbon content and calories of town gas. The emission factors of coke oven gas and blast furnace gas are set up at 0.460×10^{-4}g-C/cal and 2.990×10^{-4}g-C/cal respectively according to their respective typical composition of elements and calories.

④ **The emission factor of vegetal fuels** Since the main component of fuelwood and bagasse is cellulose, the emission factor is set up at 1.190T-C/TOE based on the composition of carbon elements and calories of cellulose. Those of the other non-commercial fuels like cattle excrement, etc. are set up at 1.190T-C/TOE as

Table 9. CO2 Emission Factors of This Work

Energy Sources	Detailed Fuels	Unit	CO2 Equivalent (tons)	C Equivalent (tons)
Coal	Hard Coal	TOE	3.905	1.065
	Brown Coal	TOE	4.088	1.115
	Coke	ton	3.182	0.868
	Patent Fuel	TOE	3.905	1.065
	BKB	TOE	4.088	1.115
	COG	cal#	1.687×10^{-4}	0.460×10^{-4}
	BFG	cal#	10.963×10^{-4}	2.990×10^{-4}
Gas	GWG	cal#	2.141×10^{-4}	0.637×10^{-4}
	Natural Gas	cal#	2.312×10^{-4}	0.631×10^{-4}
Oil	Crude Oil	ton	3.165	0.863
	NGL	ton	3.070	0.837
	Refinery Gas	ton	2.933	0.800
	LPG	ton	3.017	0.823
	Aviation Gasoline	ton	3.063	0.835
	Motor Gasoline	ton	3.132	0.854
	Jet Fuel	ton	3.157	0.861
	Kerosene	ton	3.164	0.863
	Diesel Oil	ton	3.187	0.869
	Residual Oil	ton	3.219	0.878
	Naphtha	ton	3.070	0.837
	Other Products	ton	3.220	0.878
Vegetal Fuels	Bagasse	TOE	4.366	1.190
	Fuelwood	TOE	4.366	1.190
	Charcoal	TOE	4.088	1.115
	Peat	TOE	4.088	1.115
	Other Non-Commercial Fuels	TOE	4.366	1.190

#: g-CO2/cal, g-C/cal

those of fuelwood and bagasse because suitable data are not available.

With respect to the emission factor of vegetal fuels, some argue that it should be regarded as zero because plants accumulate carbon dioxide from the atmosphere by absorbing it within themselves when growing and, if burnt, they merely return it into the atmosphere. While others argue that it could be regarded as zero if the plants once deforested are recovered through reforestation, etc., but since the use of non-commercial energies has, in fact, resulted in one of the causes of forest destruction, it should be counted by multiplying by the emission factor. Both cases are calculated in this report, but it is common that the emission from forest desruction is calculated by multiplying the destroyed area by the absorption factor per unit of area. Here, we present a case without emissions from vegetal fuels.

⑤ **The CO_2 emission factor for cement production** The CO_2 emission factor per ton of cement production is set up at 0.137T-C from the report of " U. S. EPA: Policy Options for Stabilizing Global Change, 1989, U. S. Government Printing Office."

5. The Result of the Estimate of the SOx, NOx and CO_2 Emissions and Analysis of the Trends of the Emission

(1) SOx

① The amount of the SOx emission in Asia as a whole had increased from 18.3 million tons in 1975 to 29.1 million tons in 1987 with an average annual rate of 3.9% which exceeded 3.8% of that of the primary energy consumption (See Table-10 and Figure-22).

② In the country-by-country share of the SOx emission in Asia, China was the largest and had increased her share from 56% in 1975 to 69% in 1987. In 1987, the second largest emitter was India with 10.6% followed by South Korea with 4.4%, Japan with 3.9%, and Taiwan and Thailand were both at 2.1%. These 6 countries thus accounted for 92% of the total amount of the emission.

③ In the SOx emission per unit of area by countryin Asia and by district in China and India, larger emissions were witnessed in the districts in East Asia and NIEs. In the comparison of 1987 with 1975, areas with larger emissions per unit were expanding particularly in East Asia (See Figure-24). Also, in the average annual rate of increase of the SOx emission (from 1980 to 1987) by Asian countries and by districts in China and India, inland areas in India and coastal areas in China showed a high growth rate of with more than 6%, and inland areas in China also showed a relatively high growth rate. (See Figure-23). This is due to active industrial development in coastal areas in China and a rapid growth in installations of thermal power plants, etc. according to electrification policies, etc. in inland areas of China and India where the energy consumption per unit of area was low at first.

④ In the share of the amount of the emission by energy sources in Asia as a whole, coal had the largest share with an increase from 58% in 1975 to 74% in 1987, while,on the contrary, oil decreased its share from 36% to 21%. With little emission from gas, these fossil fuels emitted 94% of the total in 1975 and 95% in 1987. Coal,with a considerably large share, exceeded the average annual growth rate of the total amount of 3.9% (from 1975 to 1987), emitting at the rate of 6.1% (See Figure-25 and Table-11).

⑤ In the share of the SOx emission by sectors in Asia as a whole, the industrial sector still accounted for the largest, though it had decreased its share from 43% in 1975 to 38% in 1987. On the contrary, the electricity generation sector had increased its share from 25% in 1975 to 30% in 1987. These two sectors accounted for 68% both in 1975 and 1987, and the next largest sector," the other" sector remained unchanged at around 17%. This meant that these three sectors accounted for 85% of the SOx emission in the Asian region, and the growth rate of the SOx emission in the electricity generation sector was particularly high with the average annual growth rate at 5.4% (from 1975 to 1987) which was considerably higher than the 3.9% rate for the total emissions. Also, high average annual growth rates were witnessed in the road transportation and the energy transformation other than electricity generation sectors, though the total amount in these sectors was rather small (See Figure-26 and Table-12).

⑥ In the amount of the SOx emission per amount of primary energy consumption by countries, the countries that were lower than the Asian average and the reason why were: the progress in the environmental measures in Japan; the high dependency on vegetal fuels in Nepal, Laos, Cambodia, Afghanistan, etc.; the dependency on gas in Brunei; the high dependency on vegetal fuels and gas in Indonesia and Bangladesh; the use of low-sulfur coal in North Korea; and the use of low-sulfur coal and vegetal fuels in India.

On the other hand, the countries that were higher than the average and the reason why were: the countries with high shares of coal and oil in the primary energy consumption and the dependence on high sulfur fuels like brown coal, etc., as in China, South Korea, Taiwan, Hong Kong, Singapore, Mongolla, Macau, etc. (See Figure-27).

⑦ During the period between 1975 and 1987, countries having decreased the amount of the SOx emission and the reason why were: environmental measures in Japan; low-sulfurization of fuels and fuel conversions to nuclear power generation, etc. in South Korea and Taiwan; the expansion of the use of gas in Malaysia; the reduction of the emission from non-ferrous metal smelting and sulfuric acid production in the Philippines (See Figure-27).

⑧ In the relations between economic levels (GDP per capita) and the amount of the SOx emission per GDP in Asia, the amount of the SOx emission tended to increase as GDP per capita increased, reaching a maximum at 1,000 to 2,000

Table 10. The Amount of the SOx Emission in Asian Region

(Unit: 1,000tons/year)

	Regions	1975	1980	1985	1986	1987
By Countries	1,China	10,175	13,372	17,259	18,326	19,989
	2,Japan	2,571	1,604	1,175	1,088	1,143
	3,India	1,652	2,010	2,833	2,921	3,074
	4,Indonesia	201	329	435	453	485
	5,S.Korea	1,159	1,918	1,366	1,355	1,294
	6,N.Korea	234	271	324	333	333
	7,Taiwan	609	1,036	693	744	605
	8,Thailand	224	420	507	528	612
	9,Pakistan	148	198	351	345	381
	10,Philippines	807	1,041	510	447	370
	11,Malaysia	193	272	271	264	263
	12,Bangladesh	40	57	46	51	49
	13,Vietnam	40	34	38	38	39
	14,Hong Kong	109	166	144	149	150
	15,Singapore	85	122	147	151	155
	16,Nepal	3.7	4.9	7.6	11.3	11.0
	17,Myanmar	17.4	30.9	30.0	32.3	29.9
	18,Sri Lanka	22.3	30.0	23.5	22.6	28.2
	19,Afghanistan	8.1	8.5	8.6	7.5	10.7
	20,Mongolia	38.7	65.1	89.7	97.0	100.5
	21,Brunei	0.4	0.9	1.1	1.0	1.1
	22,Kampuchea	1.2	1.3	2.8	2.9	2.9
	23,Laos	1.3	1.4	1.6	1.7	1.7
	24,Moldives			0.3	0.3	0.3
	25,Macau	0.9	3.0	6.2	7.1	8.4
	Asia Total	18,340	22,997	26,269	27,377	29,136
By States of Chaina	1 Beijing	295	395	401	407	415
	2 Tianjin	209	278	280	281	294
	3 Hebei	559	751	963	1,004	1,065
	4 Shanxi	400	536	734	789	838
	5 Inner Mongolia	306	392	530	609	651
	6 Liaoning	570	799	942	950	998
	7 Jilin	216	291	331	337	353
	8 Heilongjiang	337	439	514	543	583
	9 Shanghai	430	588	584	630	653
	10 Jiangsu	738	985	1,391	1,436	1,607
	11 Zhejiang	175	232	354	376	415
	12 Anhui	224	313	440	473	502
	13 Fujian	118	149	203	223	246
	14 Jiangxi	206	263	375	434	455
	15 Shandong	919	1,222	1,587	1,722	1,975
	16 Henan	536	699	890	922	982
	17 Hubei	291	393	499	537	573
	18 Hunan	299	401	522	533	551
	19 Guangdong	229	325	427	468	527
	20 Guangxi	226	285	344	388	458
	21 Sichuan	1,365	1,695	2,247	2,372	2,577
	22 Guizhou	349	436	591	632	752
	23 Yunnan	351	439	625	644	748
	24 Tibet	1	1	2	3	2
	25 Shaanxi	480	613	850	930	1,017
	26 Gansu	126	176	245	256	271
	27 Qinghai	28	37	47	54	59
	28 Ningxia	75	95	139	166	215
	29 Xinjiang	119	147	203	209	210
	China Total	10,175	13,372	17,259	18,326	19,989
By States of India	1 Assam, etc.	99	102	121	118	120
	2 Bihar, etc.	376	453	514	519	533
	3 Orissa	65	43	51	51	53
	4 Andhra Pradesh	99	111	188	196	207
	5 Tamil Nadu, etc.	122	143	268	276	284
	6 Karnataka, etc.	81	94	122	126	134
	7 Maharashtra, etc.	256	354	432	453	485
	8 Madhya Pradesh	98	124	229	237	256
	9 Gujarat	148	211	319	334	351
	10 Rajasthan	64	65	103	106	106
	11 Uttar Pradesh, etc.	178	208	302	315	341
	12 Haryana, etc.	59	97	174	182	194
	13 Jammu, Kashmir	8	7	9	9	9
	India Total	1,652	2,010	2,833	2,921	3,074

dollars of GDP per capita, and then tended to decline as GDP per capita increased. This was due to the fact that, as GDP per capita increased, vegetal fuels were converted to fossil fuels. Furthermore, energy efficiency per GDP was improved in addition to the progress in environmental measures. In the process of industrialization, the amount of the SOx emission per GDP became larger at one time (See Figure-28).

⑨ In Japan, where the SOx emission has been successfully restricted, fuel oil low-sulfurization measures by fuel oil desulfurization, etc. started around 1967 and measures have been taken by installing fluegas desulfurization units since around 1970. The results of the estimate of the amount of the SOx emission in this study indicate that out of the amount of the emission in a case where no measures were taken at all at the time of 1987, 35% would be reduced by fuel oil low-sulfurization, 36% would be reduced by fluegas desulfurization units, and the remaining 29% would be emitted (See Figure-29).

Fig. 22. The Amount of SOx Emissions in Asia by countries

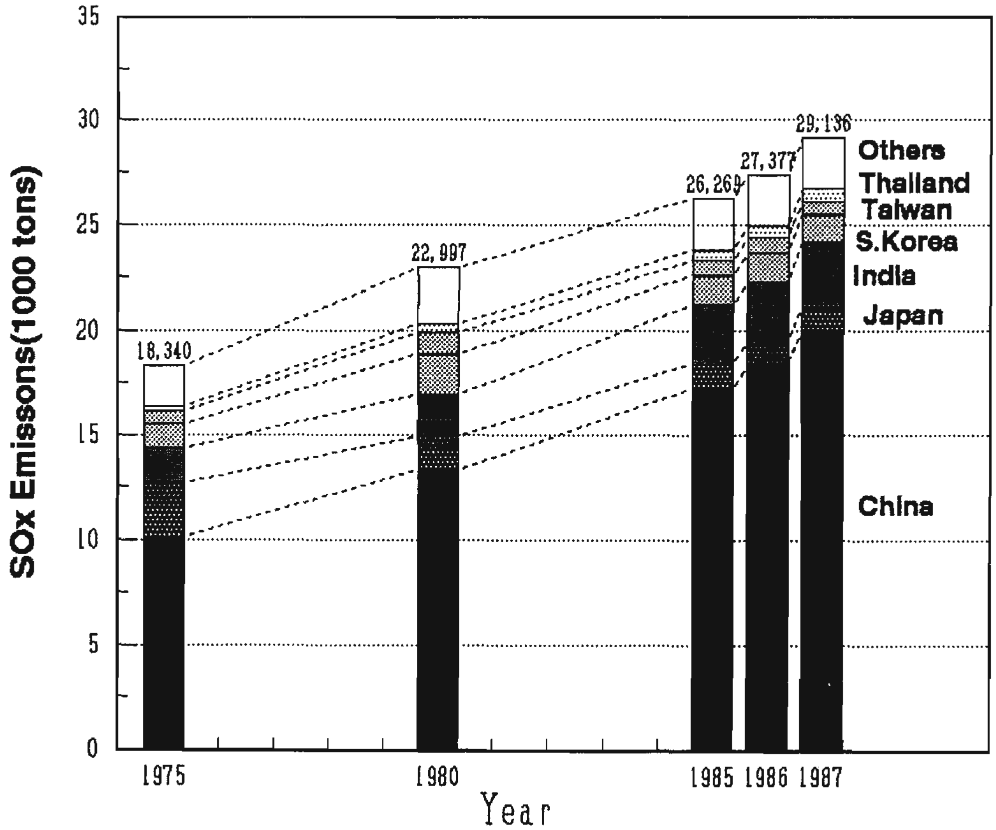


Fig. 23. Geographical Distributions of the Average Growth Rate (1987/'80) of the SOx Emissions in the Asian Region

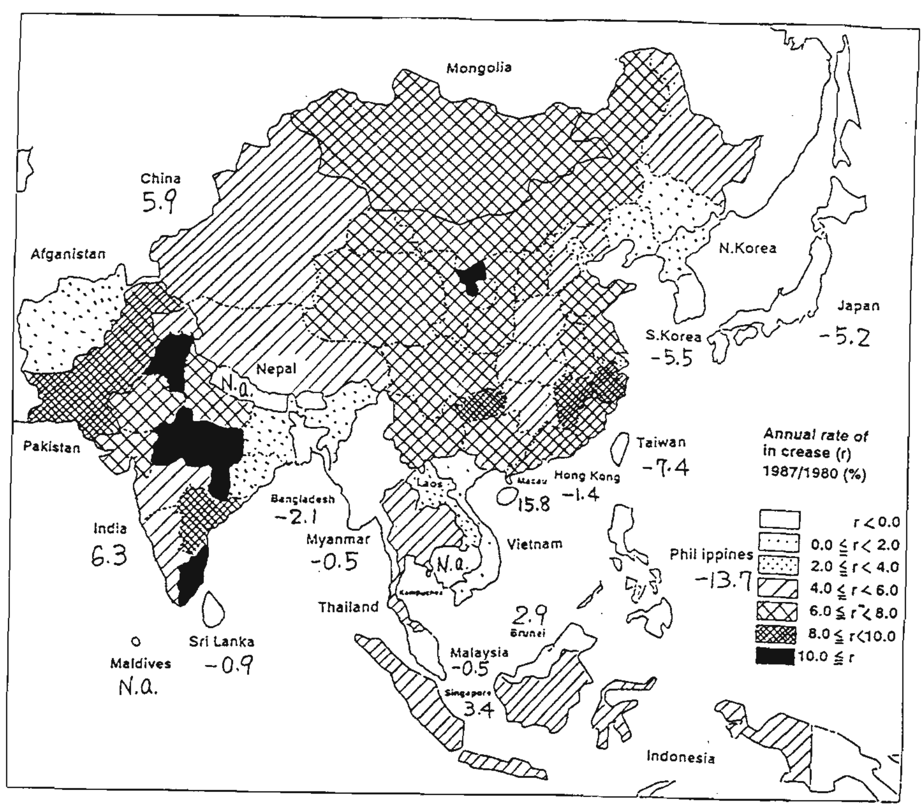
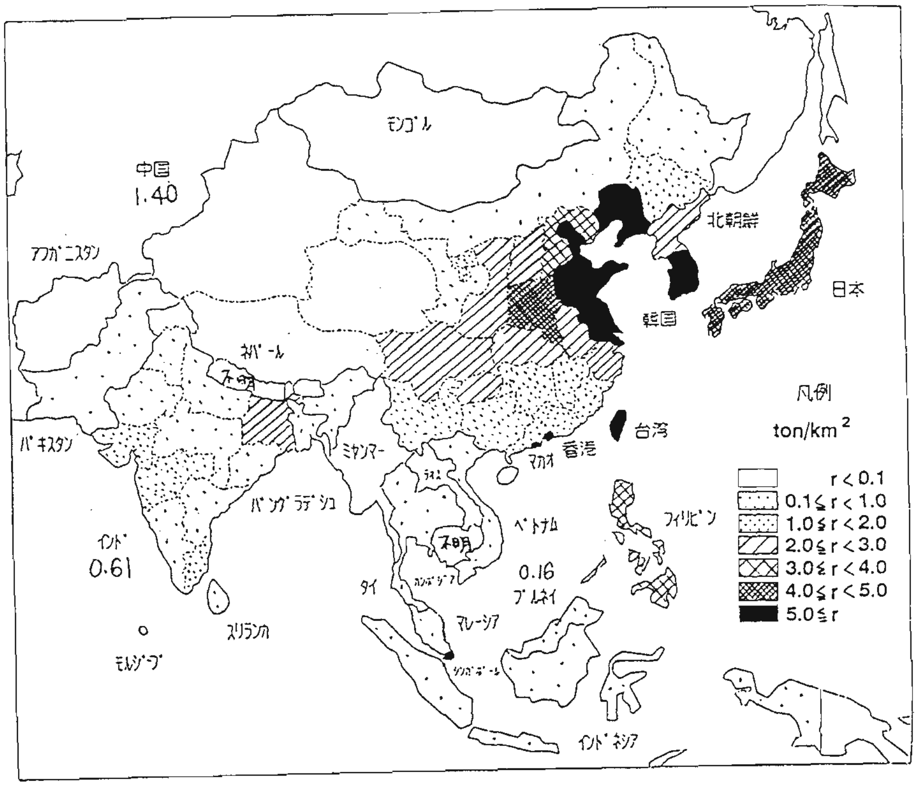


Fig. 24. Geographical Distributions of the SOx Emissions per Unit of Area in the Asian Region

(1) 1980



(2) 1987

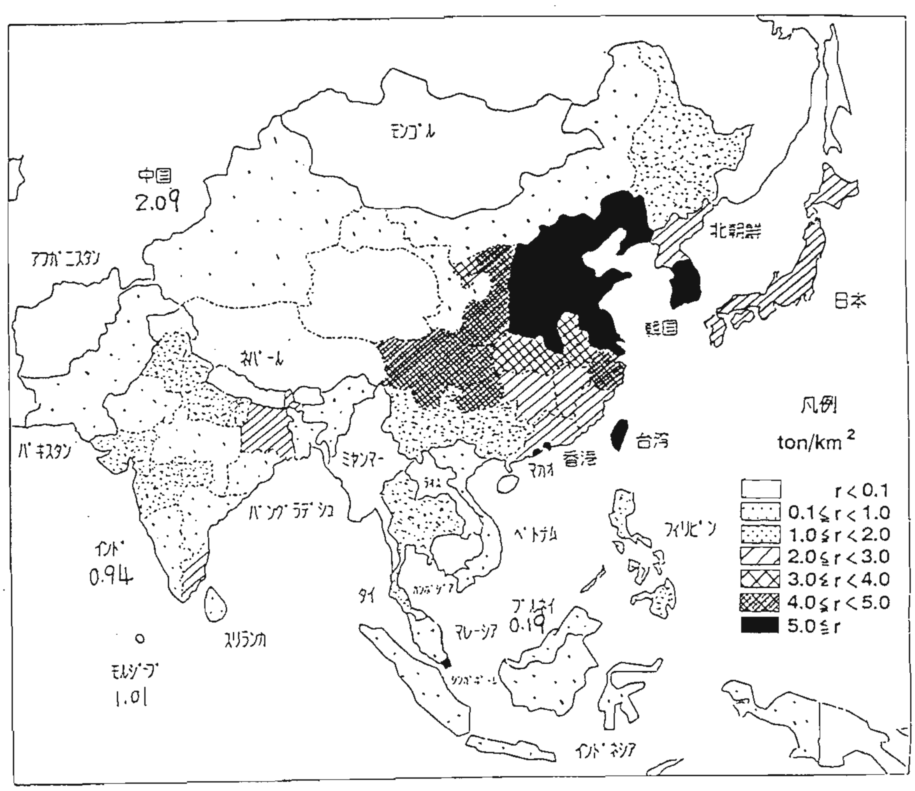


Fig. 25. SOx emissions by energy sources: Asia

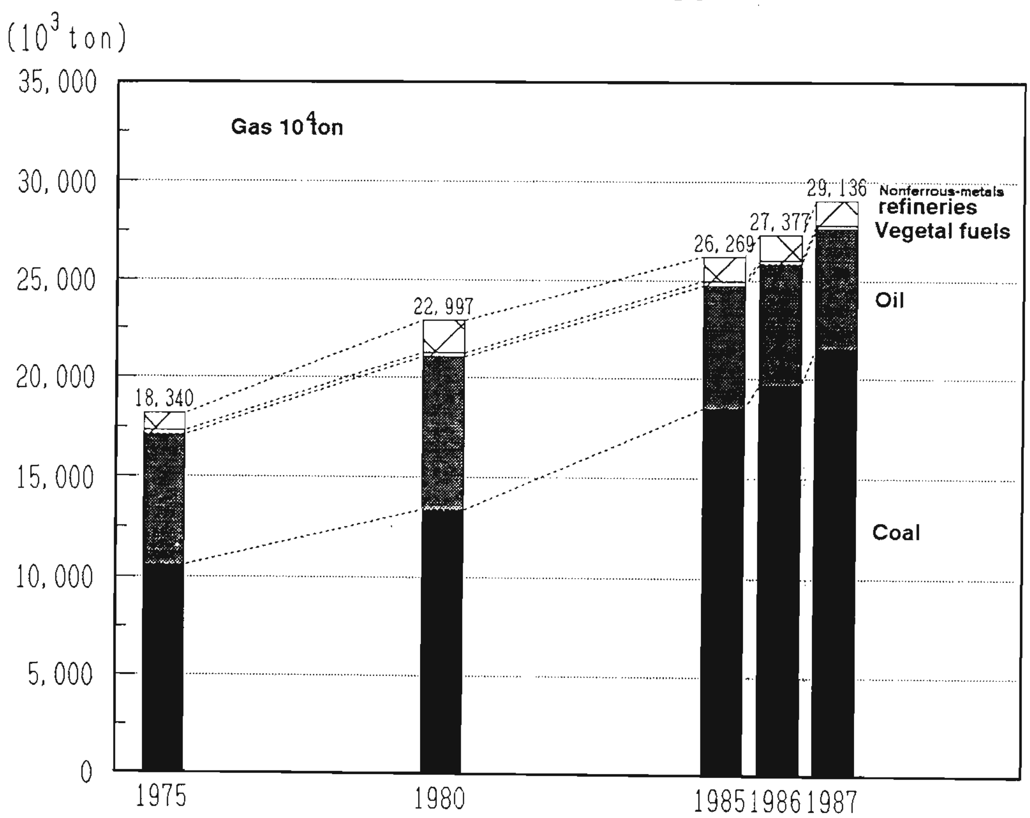


Table 11. SOx Emissions by Energy Sources: Asia

	Year	Fossil Fuels				Vegetal Fuels	Energy Sector Total	Non-Ferrous Metals	Total
		Coal	Oil	Gas	Sub-Total				
Amount of Emissions (1,000 t)	1975	10,593	6,653	3	17,249	227	17,476	864	18,340
	1980	13,384	7,719	6	21,109	207	21,317	1,680	22,997
	1985	18,531	6,252	6	24,789	229	25,018	1,251	26,269
	1986	19,673	6,187	1	25,861	234	26,095	1,282	27,377
	1987	21,525	6,125	1	27,651	237	27,888	1,248	29,136
Conposition Ratio (%)	1975	57.8	36.3	0.0	94.1	1.2	95.3	4.7	100.0
	1980	58.2	33.6	0.0	91.8	0.9	92.7	7.3	100.0
	1985	70.5	23.8	0.0	94.4	0.9	95.2	4.8	100.0
	1986	71.9	22.6	0.0	94.5	0.9	95.3	4.7	100.0
	1987	73.9	21.0	0.0	94.9	0.8	95.7	4.3	100.0
Average Annual Rates of Increase (%)	75-80	4.8	3.0	18.0	4.1	-1.8	4.1	14.2	4.6
	80-85	6.7	-4.1	0.0	3.3	2.0	3.3	-5.7	2.7
	85-87	7.8	-1.0	-69.4	5.6	1.8	5.6	-0.1	5.3
	80-87	7.0	-3.2	-28.7	3.9	2.0	3.9	-4.2	3.4
	75-87	6.1	-0.7	-12.0	4.0	0.4	4.0	3.1	3.9

Fig. 26. SOx emissions by sectors: Asia

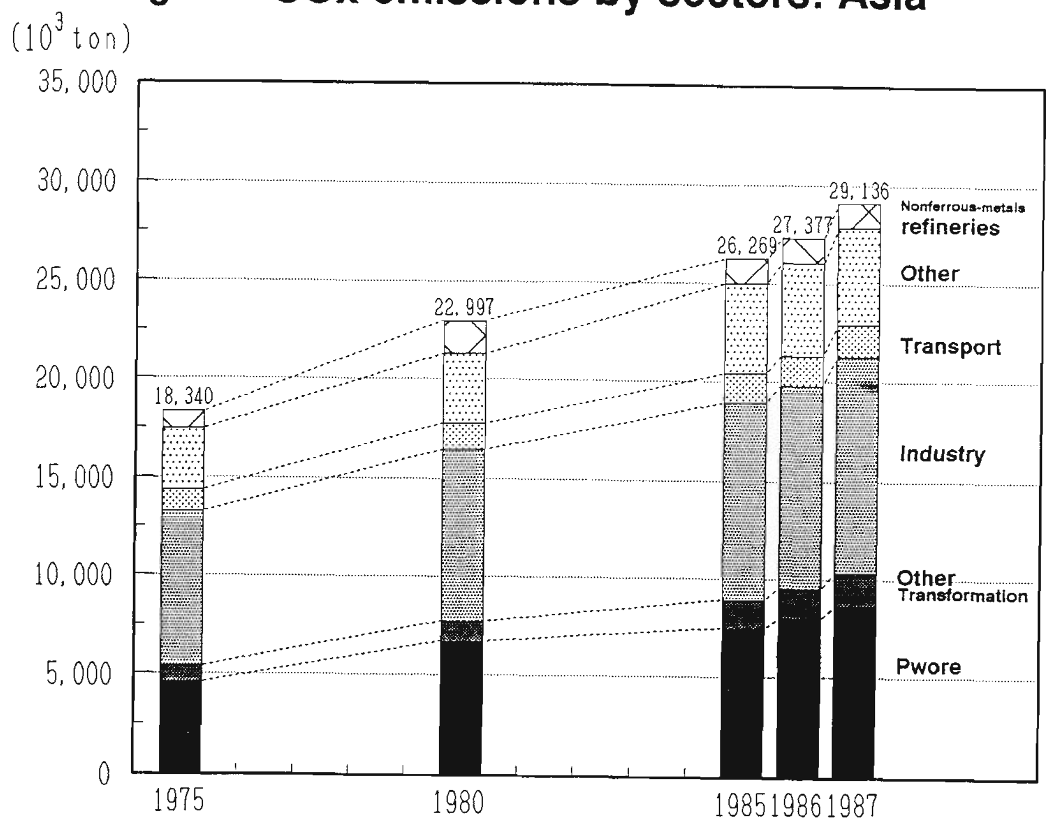


Table 12. SOx Emissions by Energy Consumption Sectors: Asia

	Year	Transformation Sectors			Final Energy Comsunption Sectors					Energy Sector Total	Non-Ferrous Metals	Total
			Electric Generat.	Others		Industry	Transport	(Road)	Others			
Amount of Emissions (1,000 t)	1975	5,470	4,639	831	12,006	7,838	1,088	303	3,080	17,476	864	18,340
	1980	7,750	6,740	1,010	13,567	8,729	1,316	469	3,523	21,317	1,680	22,997
	1985	8,965	7,502	1,464	16,052	10,021	1,451	593	4,580	25,018	1,251	26,269
	1986	9,573	8,023	1,550	16,522	10,307	1,508	638	4,708	26,095	1,282	27,377
	1987	10,355	8,704	1,651	17,533	10,995	1,633	699	4,905	27,888	1,248	29,136
Conposition Ratio (%)	1975	29.8	25.3	4.5	65.5	42.7	5.9	1.6	16.8	95.3	4.7	100.0
	1980	33.7	29.3	4.4	59.0	38.0	5.7	2.0	15.3	92.7	7.3	100.0
	1985	34.1	28.6	5.6	61.1	38.1	5.5	2.3	17.4	95.2	4.8	100.0
	1986	35.0	29.3	5.7	60.4	37.6	5.5	2.3	17.2	95.3	4.7	100.0
	1987	35.5	29.9	5.7	60.2	37.7	5.6	2.4	16.8	95.7	4.3	100.0
Average Annual Rates of Increase (%)	75-80	7.2	7.8	4.0	2.5	2.2	3.9	9.2	2.7	4.1	14.2	4.6
	80-85	3.0	2.2	7.7	3.4	2.8	2.0	4.8	5.4	3.3	-5.7	2.7
	85-87	7.5	7.7	6.2	4.5	4.7	6.1	8.6	3.5	5.6	-0.1	5.3
	80-87	4.2	3.7	7.3	3.7	3.4	3.1	5.9	4.8	3.9	-4.2	3.4
	75-87	5.5	5.4	5.9	3.2	2.9	3.4	7.2	4.0	4.0	3.1	3.9

Fig. 27. SOx emission related to the amounts of the primary energy consumption (including vegetal fuels): Asian countries

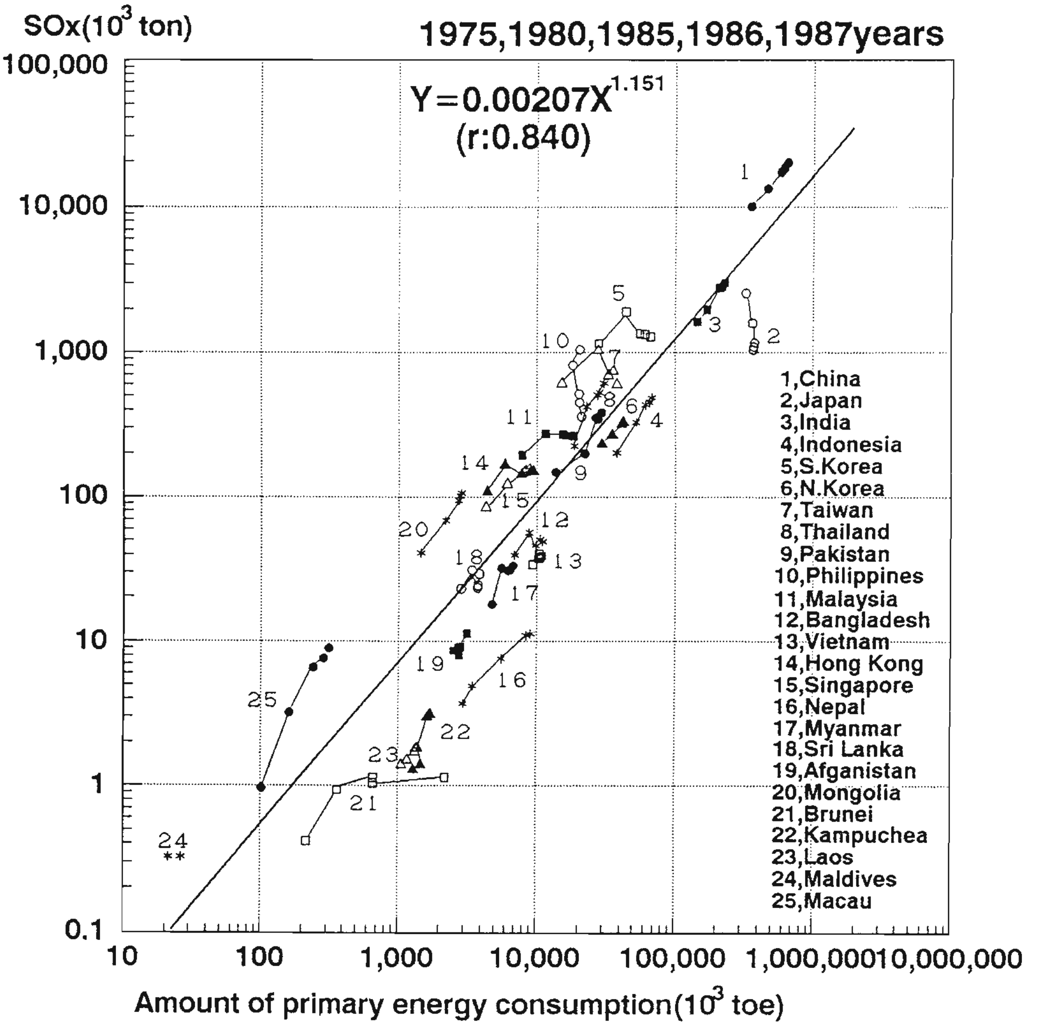


Fig. 28. Relations between Economic Levels and SOx Emissions per GDP in Asian Countries

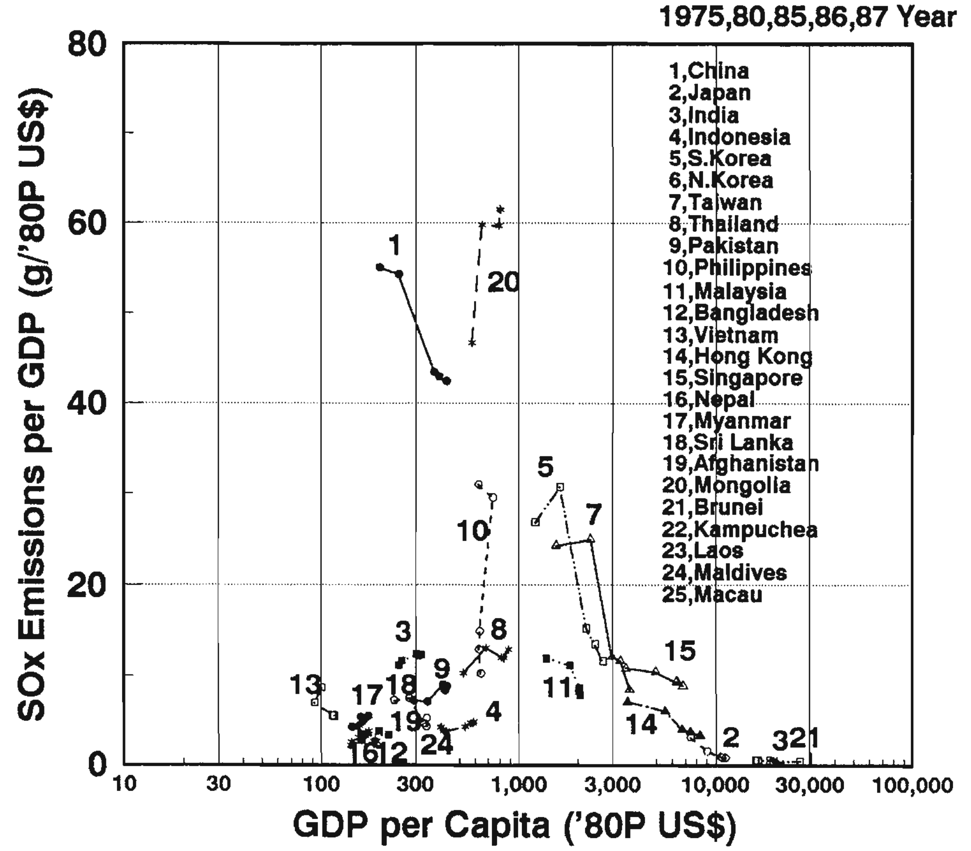
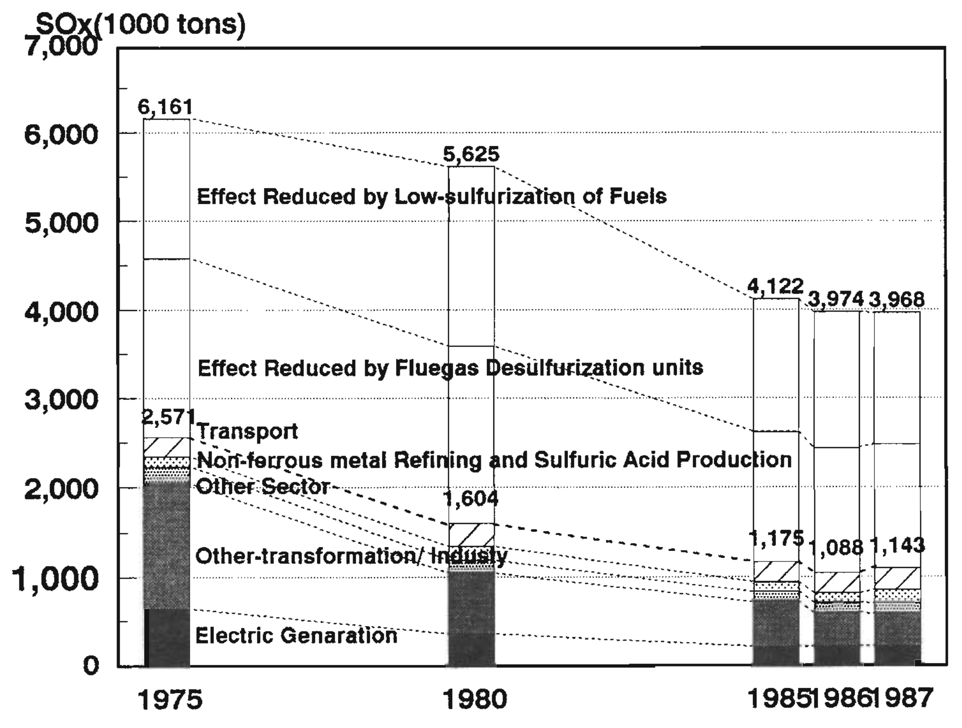


Fig. 29. SOx Emissins and the Effect of Environmental Measures in Japan



(2) **NOx**

① The amount of the NOx emission in Asia as a whole reached 15.4 million tons in 1987 from 9.4 million tons in 1975, increasing at an average annual rate of 4.3%. This exceeds the 3.8% for the primary energy consumption and 3.9% for SOx (See Table-13 and Figure-30).

② In the country-by-country share of the NOx emission in Asia, China was the largest, though smaller than the share of SOx, and had increased its share from 40% in 1975 to 48% in 1987. In 1987, the second largest emitter was India with 16.5%, followed by Japan with 12.5%, Indonesia with 4.1%, South Korea with 3.6%, North Korea with 3.1%. These 6 countries thus accounted for 87% of the total emissions in Asia.

③ In the NOx emission per unit of area by country in Asia and by district in China and India, like SOx, larger emissions were witnwessed in the districts in NIEs and East Asia. In the comparison of 1987 with 1975, areas with larger emissions per unit were expanding particularly in East Asia (See Figure-32). Also, in the average annual growth rate of the NOx emission (from 1980 to 1987) by country and by district in China and India, inland areas in India and coastal areas in China showed high growth with more than 8%, with inland areas in China also showing a relatively high growth rate. The reason is considered to be the same as in the case of SOx (See Figure-31).

④ In the share of amount of the emission by energy sources in Asia as a whole, coal had the largest share with an increase from 44% in 1975 to 56% in 1987, while, on the contrary, oil decreased its share from 45% to 35%. With about 1% emissions from gas, these fossil fuels emitted 89% of the total in 1975 and 92% in 1987. Coal, with the largest share, exceeding considerably the average annual growth rate of the total amount of 4.2%, emitted at the rate of 6.3% (See Figure-33 and Table-14).

⑤ In the share of the NOx emission by sectors in Asia as a whole, the industrial sector accounted for the largest share, though it had decreased from 33% in 1975 to 31% in 1987. The next largest sector, the electricity generation sector had increased its share considerably from 20% in 1975 to 27% in 1987, while the third largest sector the transportation sector (mobile sources) had decreased its share from 28% to 25%. Particularly, the growth rate of the NOx emission in the

electricity generation sector was high with an average annual growth rate of 7.0% (from 1975 to 1987) which was considerably higher than the 4.2% of the total emissions.
(See Figure-34 and Table-15).

⑥ In the amount of the NOx emission per amount of the primary energy consumption by country, more varied for the Asian average than SOx, Japan with the progress in the environmental measures, and Nepal, Bangladesh, Cambodia, etc. with the high dependency on vegetal fuels were lower than the Asian average, and China, India, Mongol, etc. with the high dependency on coal were higher than the average (See Figure-35).

⑦ During the period between 1975 and 1987, countries which decreased the amount of the NOx emission and the reason why were Japan, which had progressed in environmental measures, and Viet Nam, which had decreased fuel consumption in the transportation sector, while the other countries including South Korea and Taiwan, which had decreased the SOx emission, increased the NOx emission.

⑧ In the relations between economic levels (GDP per capita) and the amount of NOx emission per GDP in Asia, the amount of NOx emission per GDP decreased as GDP per capita increased. In the process of industrialization, however, the amount of SOx emission per GDP became larger for some time as witnessed in South Korea, Taiwan, etc. (See Figure-36).

⑨ In Japan, where the NOx emission has been successfully restricted, combustion efficiency had been managed and low NOx burners had been installed, measures had been taken by installments of denitration units from around 1972, and by regulations on automobile exhaust gas emissions since 1978. The results of the estimate of the amount of the NOx emission in this study indicate that out of the amount of the emission in a case where no measures were taken at all, 18% would be reduced and 82% would be emitted in 1975 and 40% would be reduced and the remaining 60% would be emitted in 1987. By emission sources, stationary sources accounted for 30% in 1975 and 48% in 1987 in the rate of the reduction, and mobile sources for 4% in 1975 and 33% in 1987. The amount of emissions from the stationary sources remained unchanged because the effect was offset by increasing number of automobiles, etc. (See Figures-37, -38, -39).

Table 13. The Amount of the NOx Emission in Asian Region

(Unit: 1,000tons/year)

	Regions	1975	1980	1985	1986	1987
By Countries	1,China	3,727	4,907	6,361	6,772	7,371
	2,Japan	2,329	2,132	1,948	1,901	1,935
	3,India	1,379	1,673	2,312	2,401	2,556
	4,Indonesia	331	465	561	600	639
	5,S.Korea	220	365	464	499	555
	6,N.Korea	325	383	456	468	468
	7,Taiwan	124	225	261	300	325
	8,Thailand	182	255	327	341	384
	9,Pakistan	101	164	193	201	231
	10,Philippines	172	184	173	177	184
	11,Malaysia	90	126	167	171	177
	12,Bangladesh	46	58	61	65	66
	13,Vietnam	120	88	95	98	99
	14,Hong Kong	51	67	106	119	134
	15,Singapore	43	67	81	84	88
	16,Nepal	18	21	34	53	50
	17,Myanmar	38	47	50	53	45
	18,Sri Lanka	23	31	34	33	37
	19,Afghanistan	20	22	24	22	30
	20,Mongolia	31	49	66	71	72
	21,Brunei	2.0	4.0	8.1	7.7	11.1
	22,Kampuchea	8.6	9.3	11.7	12.1	12.3
	23,Laos	7.9	8.0	8.7	8.9	9.1
	24,Moldives			0.5	0.6	0.6
	25,Macau	2.1	2.9	3.7	4.8	5.0
	Asia Total	9,388	11,352	13,805	14,462	15,483
By States of Chaina	1 Beijing	167	226	258	268	267
	2 Tianjin	106	141	151	154	165
	3 Hebei	265	353	471	489	514
	4 Shanxi	175	235	329	358	387
	5 Inner Mongolia	98	129	173	203	219
	6 Liaoning	329	446	547	546	583
	7 Jilin	151	201	243	248	263
	8 Heilongjiang	209	277	351	369	400
	9 Shanghai	185	255	263	283	298
	10 Jiangsu	217	282	403	425	489
	11 Zhejiang	80	103	161	175	197
	12 Anhui	104	140	198	215	232
	13 Fujian	49	61	83	95	111
	14 Jiangxi	73	95	137	150	158
	15 Shandong	256	342	451	497	566
	16 Henan	229	300	384	399	428
	17 Hubei	139	181	233	253	271
	18 Hunan	145	183	242	255	269
	19 Guangdong	114	146	200	223	261
	20 Guangxi	63	78	96	106	123
	21 Sichuan	211	267	345	364	396
	22 Guizhou	56	73	95	100	116
	23 Yunnan	61	77	107	112	132
	24 Tibet	1	2	2	3	3
	25 Shaanxi	94	122	168	181	198
	26 Gansu	59	77	112	118	123
	27 Qinghai	19	25	34	38	41
	28 Ningxia	18	23	34	45	56
	29 Xinjiang	53	68	94	98	105
	China Total	3,727	4,907	6,361	6,772	7,371
By States of India	1 Assam, etc.	33	41	44	45	47
	2 Bihar, etc.	298	353	393	401	419
	3 Orissa	61	47	55	55	57
	4 Andhra Pradesh	91	105	162	169	181
	5 Tamil Nadu, etc.	64	110	203	210	221
	6 Karnataka, etc.	94	110	131	135	141
	7 Maharashtra, etc.	193	269	334	353	379
	8 Madhya Pradesh	97	117	211	219	237
	9 Gujarat	113	151	226	237	250
	10 Rajasthan	53	59	81	83	87
	11 Uttar Pradesh, etc.	191	218	311	325	354
	12 Haryana, etc.	55	86	154	161	174
	13 Jammu, Kashmir	6	7	8	8	9
	India Total	1,379	1,673	2,312	2,401	2,556

Fig. 30. The Amount of NOx Emissions in Asia by countries

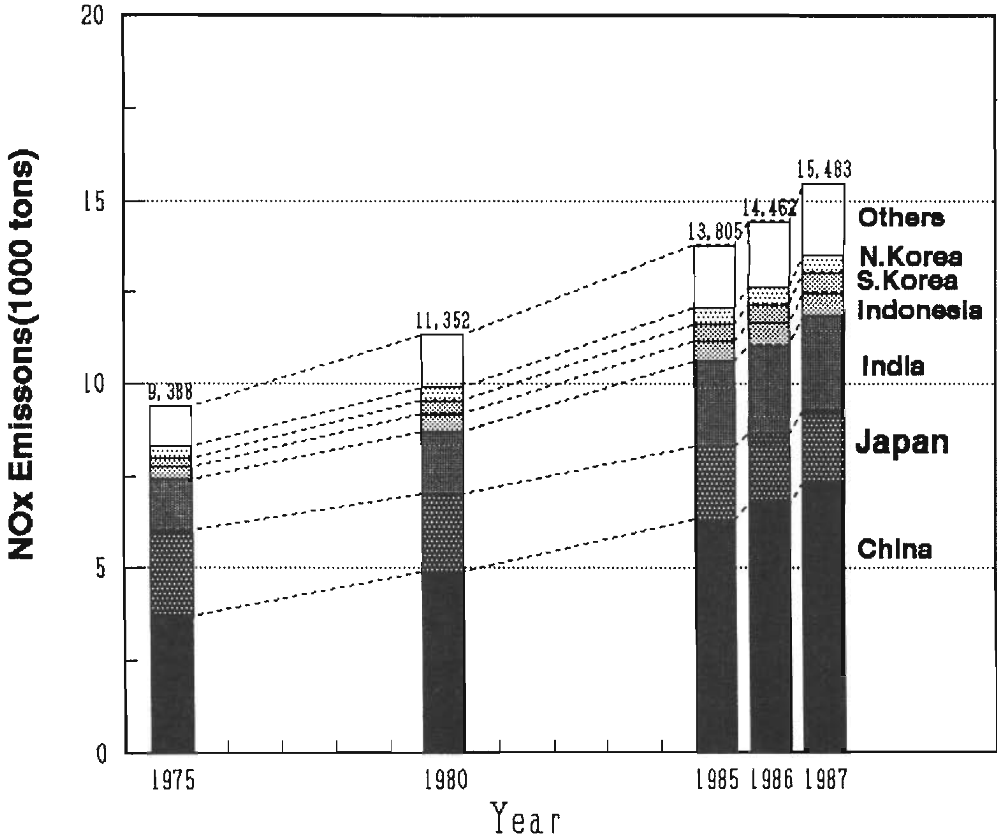


Fig. 31. Geographical Distributions of the Average Growth Rate (1987/'80) of the NOx Emissions in the Asian Region

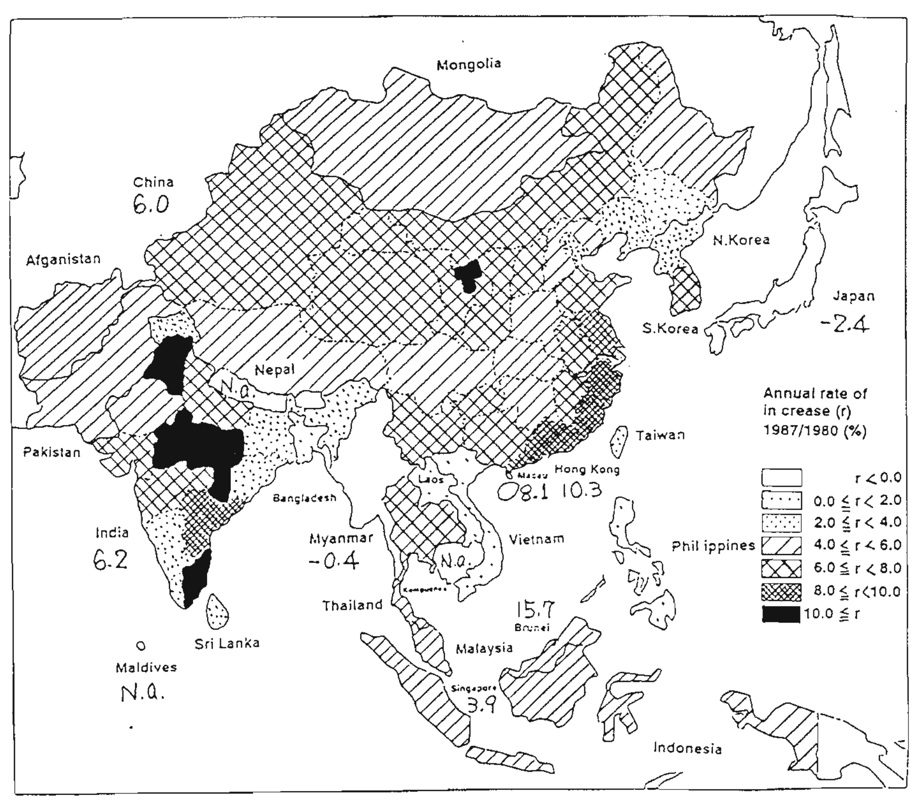
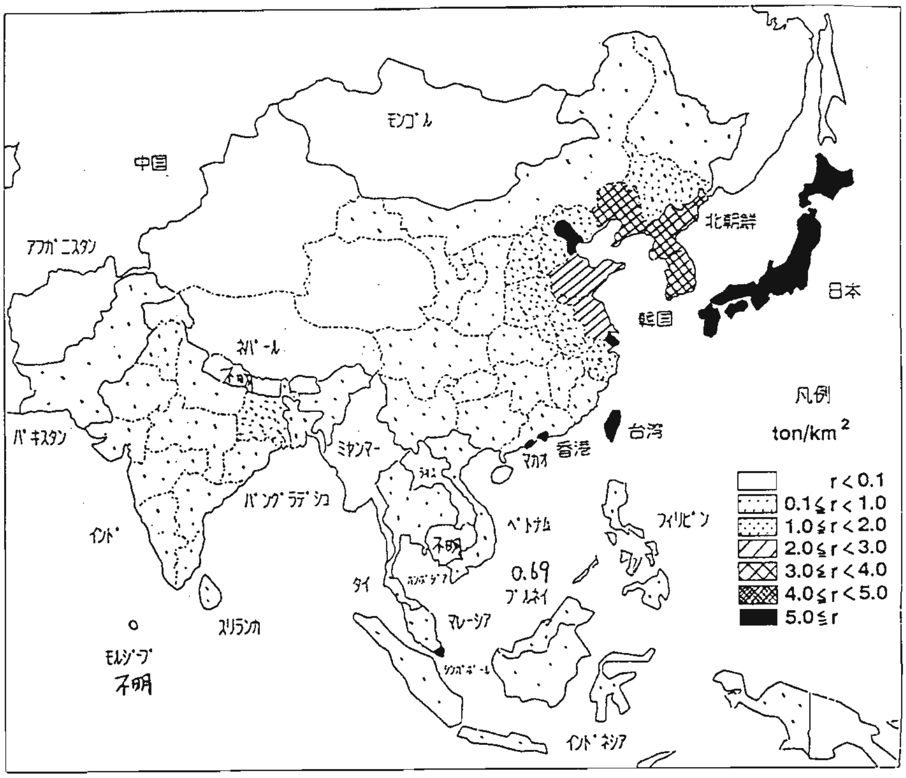


Fig. 32. Geographical Distributions of the NOx Emissions per Unit of Area in the Asian Region

(1) 1980



(2) 1987

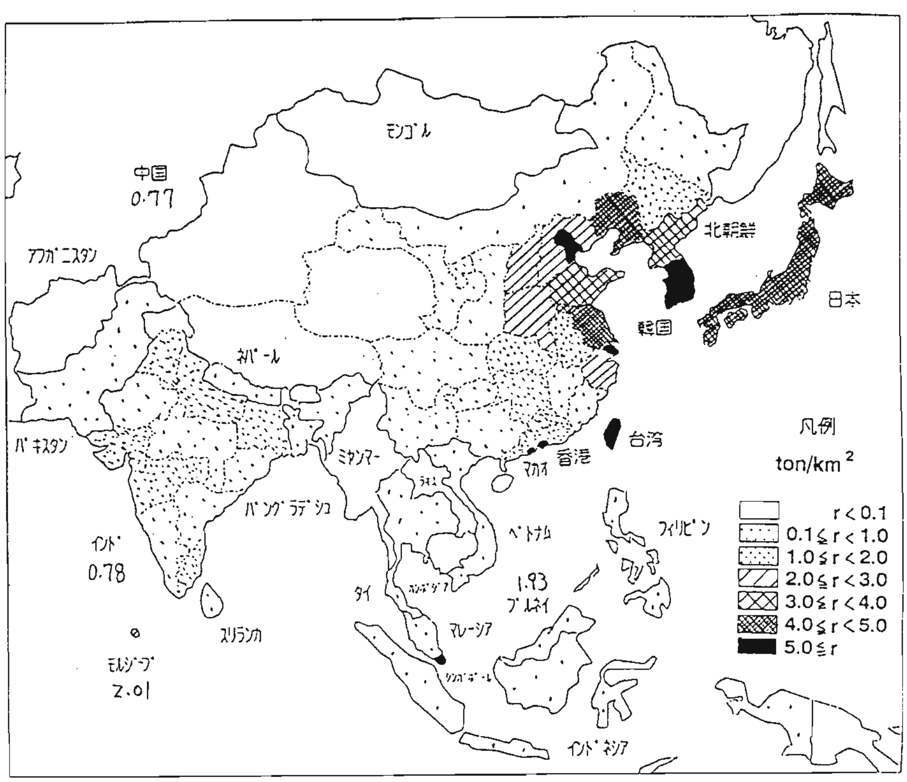


Fig. 33. NOx emissions by energy sources: Asia

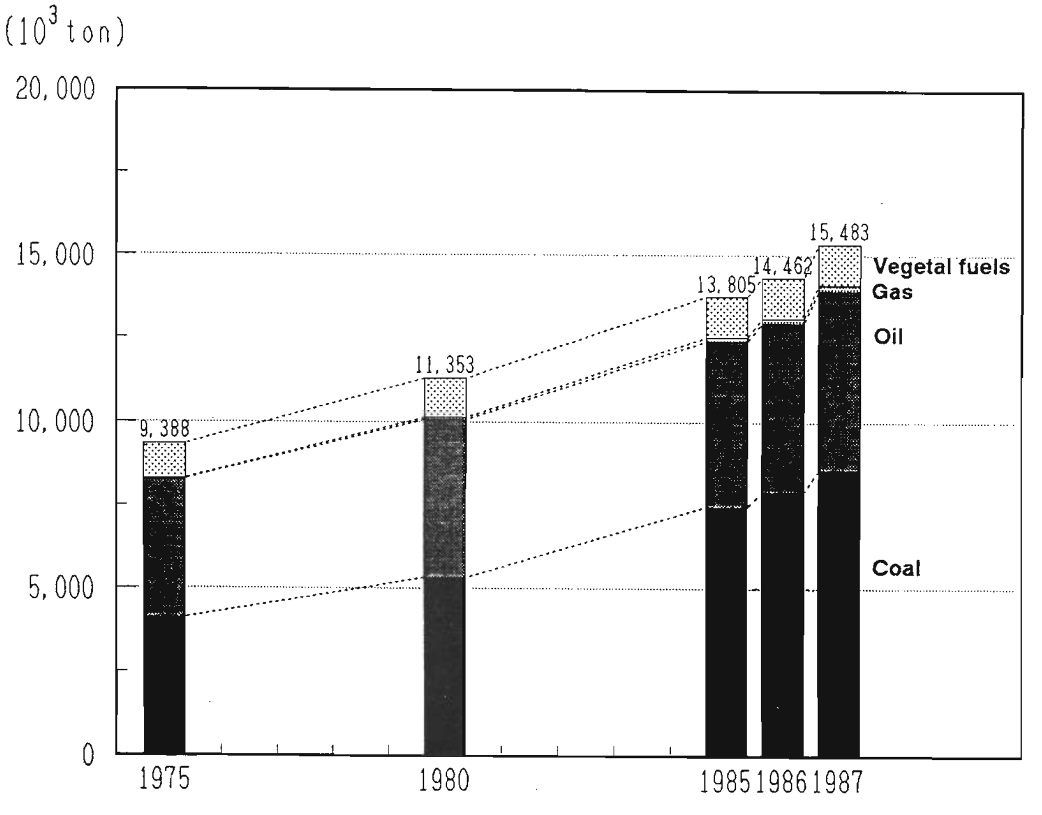


Table 14. NOx Emissions by Energy Sources: Asia

	Year	Fossil Fuels Coal	Oil	Gas	Sub-Total	Vegetal Fuels	Total
Amount of Emissions (1,000 t)	1975	4,134	4,178	47	8,360	1,029	9,388
	1980	5,328	4,795	84	10,207	1,145	11,353
	1985	7,477	4,978	117	12,573	1,232	13,805
	1986	7,990	5,052	156	13,198	1,264	14,462
	1987	8,651	5,369	182	14,203	1,280	15,483
Conposition Ratio (%)	1975	44.0	44.5	0.5	89.0	11.0	100.0
	1980	46.9	42.2	0.7	89.9	10.1	100.0
	1985	54.2	36.1	0.9	91.1	8.9	100.0
	1986	55.2	34.9	1.1	91.3	8.7	100.0
	1987	55.9	34.7	1.2	91.7	8.3	100.0
Average Annual Rates of Increase (%)	75-80	5.2	2.8	12.2	4.1	2.2	3.9
	80-85	7.0	0.8	6.9	4.3	1.5	4.0
	85-87	7.6	3.9	24.5	6.3	1.9	5.9
	80-87	7.2	1.6	11.6	4.8	1.6	4.5
	75-87	6.3	2.1	11.9	4.5	1.8	4.3

Fig. 34. NOx emissions by sectors: Asia

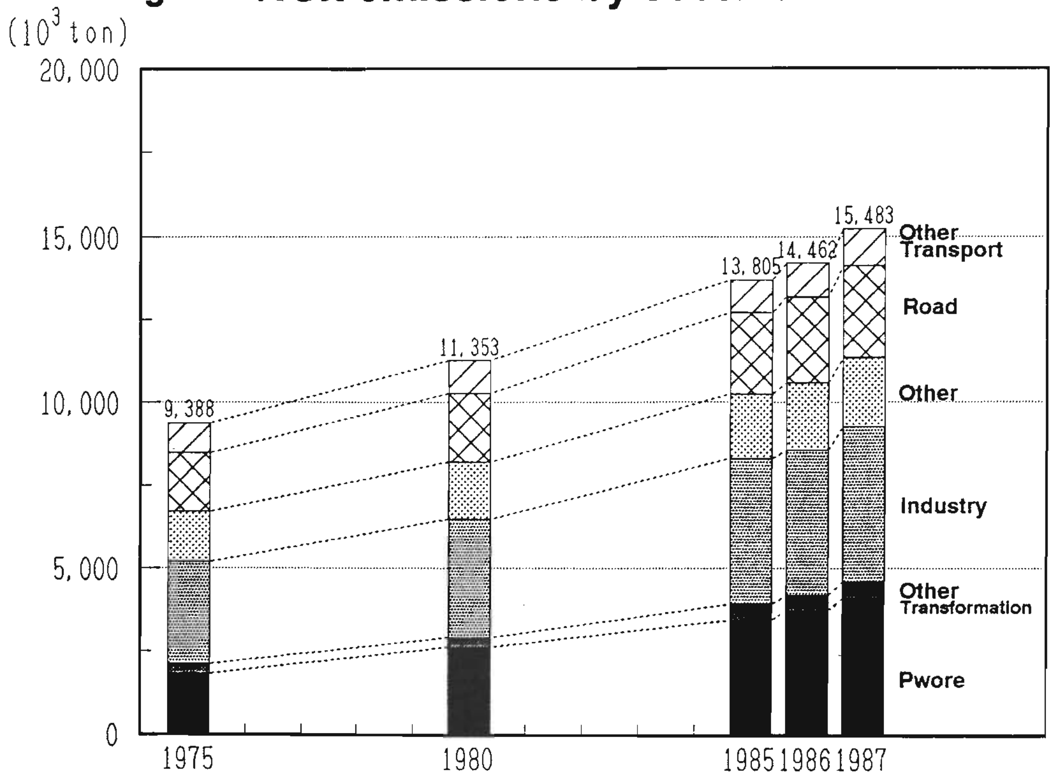


Table 15. NOx Emissions by Energy Consumption Sectors: Asia

(単位：1000 t)

	Year	Transformation Sectors			Final Energy Comsunption Sectors					Total
			Electric Generat.	Others		Industry	Transport	(Road)	Others	
Amount of Emissions (1,000 t)	1975	2,121	1,829	292	7,267	3,106	2,649	1,757	1,512	9,388
	1980	3,002	2,629	373	8,351	3,595	3,044	2,054	1,711	11,353
	1985	4,042	3,452	590	9,764	4,379	3,447	2,452	1,938	13,805
	1986	4,328	3,720	608	10,134	4,501	3,632	2,590	2,001	14,462
	1987	4,742	4,099	643	10,741	4,799	3,887	2,779	2,055	15,483
Conposition Ratio (%)	1975	22.6	19.5	3.1	77.4	33.1	28.2	18.7	16.1	100.0
	1980	26.4	23.2	3.3	73.6	31.7	26.8	18.1	15.1	100.0
	1985	29.3	25.0	4.3	70.7	31.7	25.0	17.8	14.0	100.0
	1986	29.9	25.7	4.2	70.1	31.1	25.1	17.9	13.8	100.0
	1987	30.6	26.5	4.2	69.4	31.0	25.1	17.9	13.3	100.0
Average Annual Rates of Increase (%)	75-80	7.2	7.5	5.0	2.8	3.0	2.8	3.2	2.5	3.9
	80-85	6.1	5.6	9.6	3.2	4.0	2.5	3.6	2.5	4.0
	85-87	8.3	9.0	4.4	4.9	4.7	6.2	6.5	3.0	5.9
	80-87	6.7	6.6	8.1	3.7	4.2	3.6	4.4	2.7	4.5
	75-87	6.9	7.0	6.8	3.3	3.7	3.2	3.9	2.6	4.3

Fig. 35. NOx emission related to the amounts of the primary energy consumption (including vegetal fuels): Asian countries

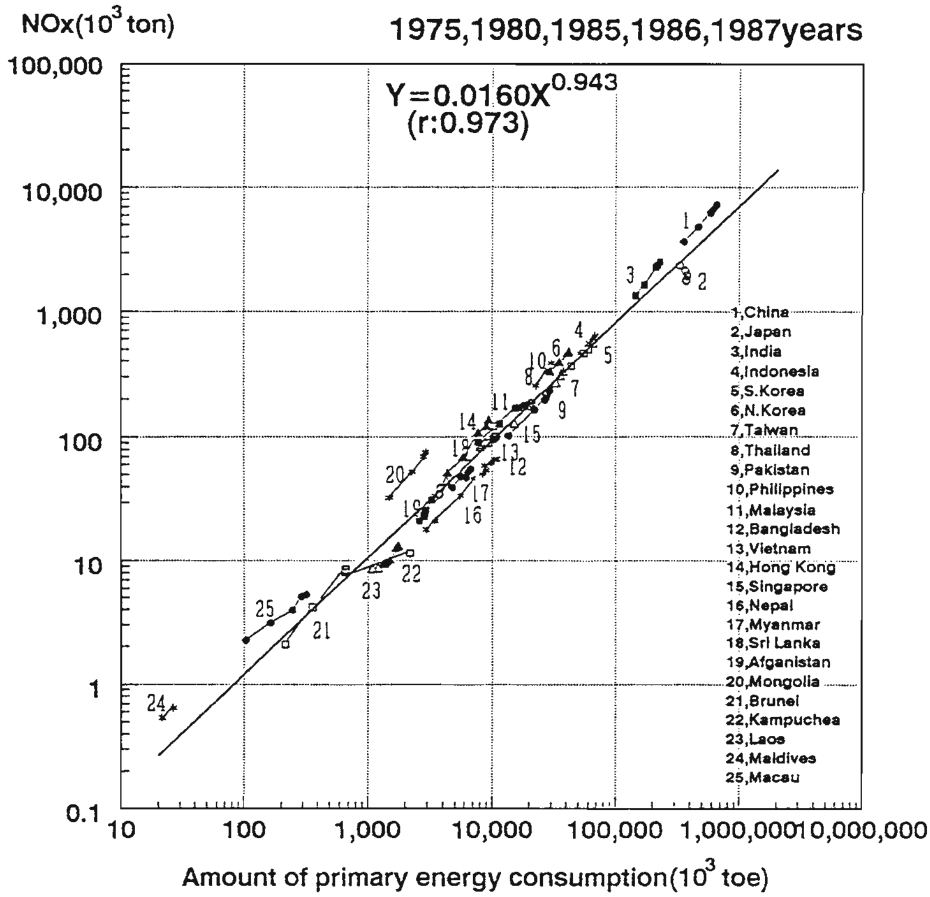


Fig. 36. Relations between Economic Levels and NOx Emissions per GDP Asian Countries

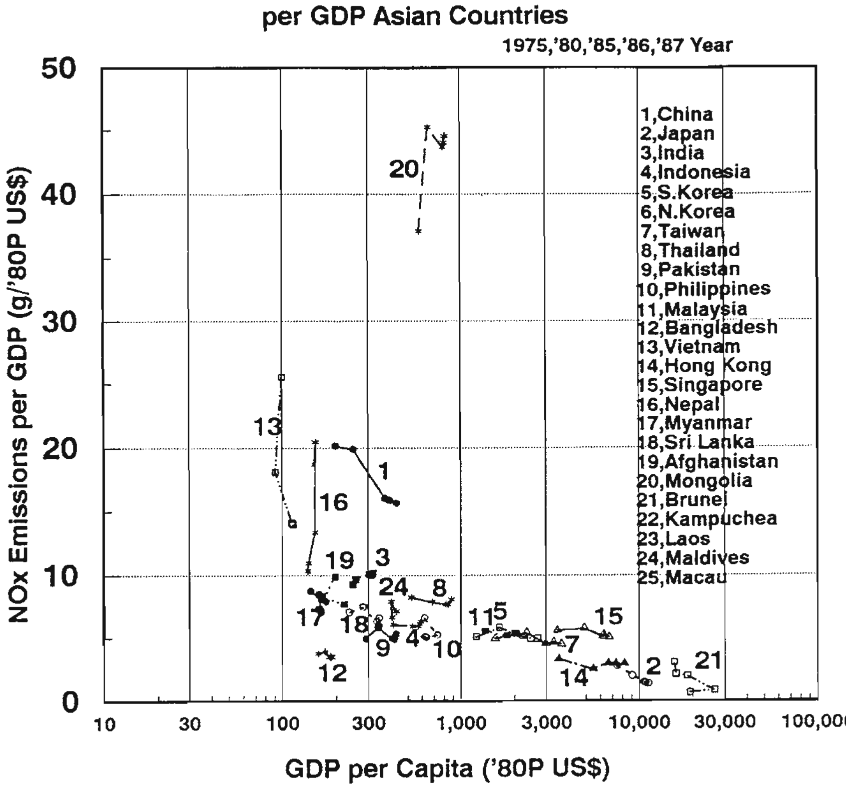


Fig. 37. NOx Emissins and the Effect of Environmental Measures in Japan

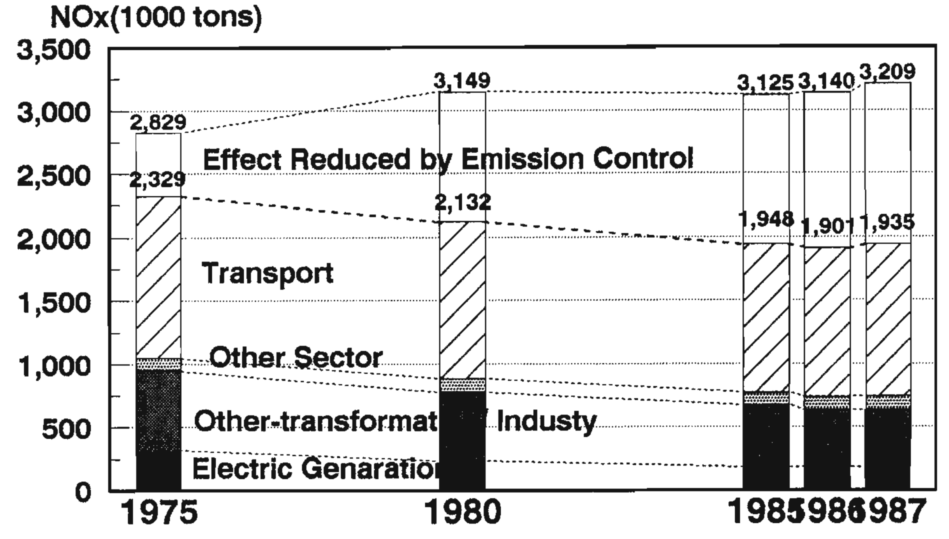


Fig. 38. NOx Emissins from Stationary Sources and the Effect of Environmental Measures in Japan

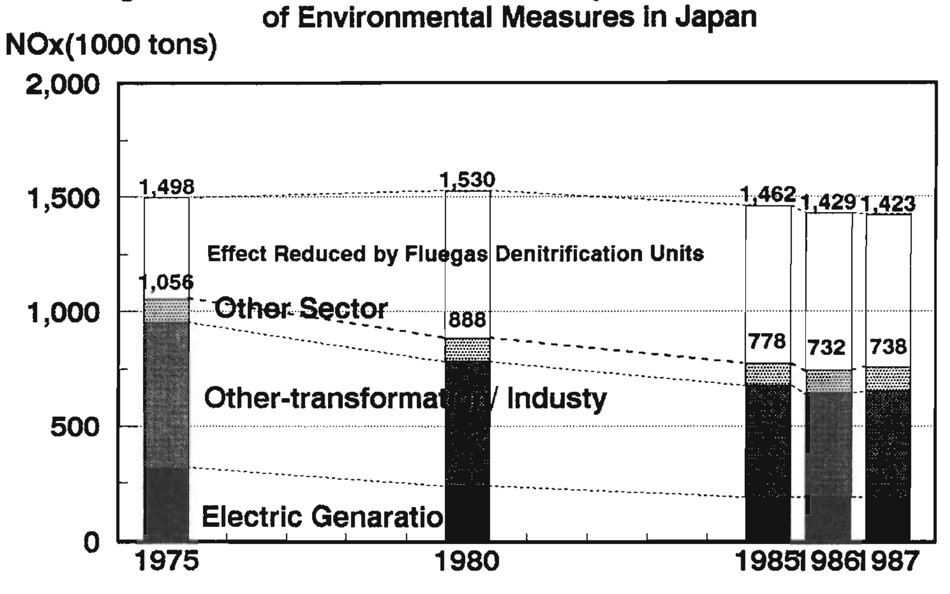
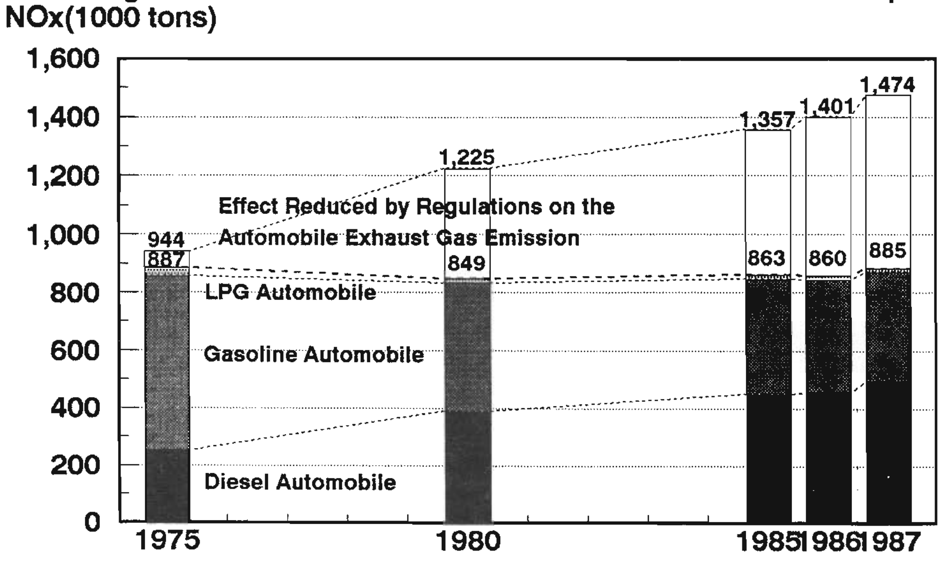


Fig. 39. NOx Emissins from Automobile Sources (Road) and Effect for Regulations on the Automobile Exhaust Gas Emission in Japan



(3) CO_2

① The amount of the CO_2 emission (equivalent to C) in Asia as a whole reached 1.23 billion tons in 1987 from 0.78 billion tons in 1975, increasing on an average annual rate of 3.9%, which is slightly higrer than the 3.8% rate for the primary energy consumption.
In this connection, as the total amount of the CO_2 emission, including emissions from vegetal fuels, was 0.98 billion tons in 1975 and 1.48 billion tons in 1987, the amount of emissions from vegetal fuels were 0.2 billion tons and 0.25 billion tons respectively. The consumption of the fuelwood, which is the main component of vegetal fuels, could affect the reduction of tropical forests, but in this report the emission is estimated at the minimum, assuming that the CO_2 emission from vegetal fuels be re-fixed by the same amount of plants by reforestation (See Table-16 and Figure-40).

② In the country-by-country share of the CO_2 emission in Asia (excluding vegetal fuels), China was the largest, increasing her share from 41% in 1975 to 49% in 1987. In 1987, the second largest emitter was Japan with 22.1% followed by India with 10.6%, South Korea with 4.3%, North Korea with 3.2%, and Indonesia with 2.4%. These 6 countries thus accounted for 91% of the total emissions in Asia.

③ In the CO_2 emission per unit of area by country in Asia and by district in China and India, like SOx and NOx, larger emissions were witnwessed in the districts in NIEs and East Asian countries. In the comparison of 1987 with 1975, areas with larger emissions per unit were expanding (See Figure-42). The average annual rate of increase of the CO_2 emission (from 1980 to 1987) by Asian country and by district in China and India showed almost the same geographical distribution as in SOx and NOx, with the central part of India and coastal areas in China showing higher growth rates of more than 8%. The reason for that is the same as in the case stated about SOx (See Figure-41).

④ In the share of the amount of the CO_2 emission by energy source in Asia as a whole, coal had the largest share with an increase from 53% in 1975 to 59% in 1987, and oil decreased its share from 41% to 32%. Also, gas, though the amount of emission was small, increased its share from 2% in 1975 to 5% in 1987, and thus the total fossil fuels emitted 96% both in 1975 and 1987. The remaining 4% was emitted by raw materials for cement production (See Figure-43 and Table-17).

Table 16. The Amount of the CO2 Emission in Asian Region
Excluding Emissions from Vegetal Fuels (Unit: 1,000tons-C/year)

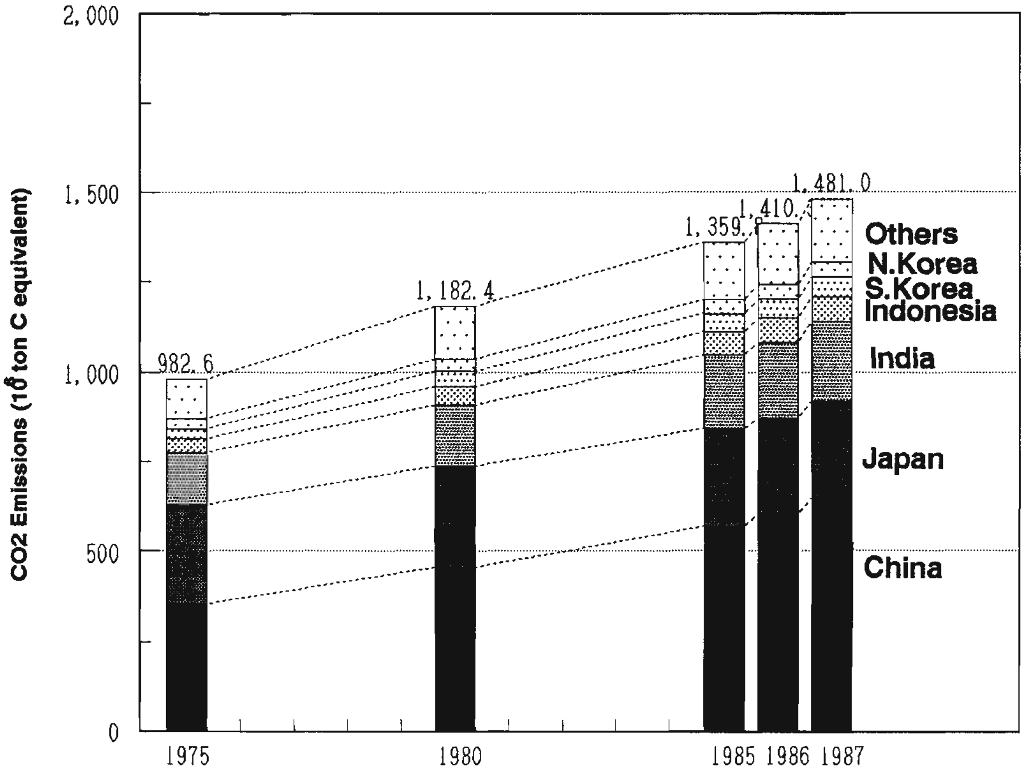
	Regions	1975	1980	1985	1986	1987
By Countries	1,China	317,031	413,480	519,636	550,984	596,205
	2,Japan	271,945	281,165	272,059	269,933	271,786
	3,India	70,194	87,268	120,520	123,879	130,507
	4,Indonesia	11,219	21,194	26,251	28,222	29,888
	5,S.Korea	22,990	38,337	47,754	50,023	53,250
	6,N.Korea	28,333	33,139	38,324	39,029	39,055
	7,Taiwan	11,961	21,422	21,624	24,657	26,337
	8,Thailand	7,397	11,034	13,899	14,330	16,679
	9,Pakistan	6,124	8,700	12,101	12,502	13,759
	10,Philippines	8,892	10,259	8,665	8,781	9,164
	11,Malaysia	5,086	7,311	9,357	9,679	10,052
	12,Bangladesh	1,290	1,919	2,355	2,635	2,839
	13,Vietnam	5,690	4,292	4,574	4,749	4,815
	14,Hong Kong	3,590	5,200	7,539	8,466	9,330
	15,Singapore	3,521	5,186	6,050	6,261	6,414
	16,Nepal	95	146	195	186	211
	17,Myanmar	1,145	1,507	1,757	1,934	1,559
	18,Sri Lanka	845	1,167	1,083	1,109	1,250
	19,Afghanistan	524	424	908	800	1,065
	20,Mongolia	1,119	1,901	2,456	2,589	2,676
	21,Brunei	134	253	489	482	1,365
	22,Kampuchea	20		117	121	121
	23,Laos	70	53	57	58	58
	24,Moldives			19	23	23
	25,Macau	84	140	202	243	268
	Asia Total	779,297	955,492	1,117,990	1,161,673	1,228,676
By States of Chaina	1 Beijing	13,505	19,007	20,484	21,182	21,744
	2 Tianjin	8,838	12,005	11,911	12,269	13,076
	3 Hebei	21,921	28,443	37,232	38,564	40,606
	4 Shanxi	15,529	20,146	27,442	28,959	30,374
	5 Inner Mongolia	8,885	11,597	14,949	16,828	18,014
	6 Liaoning	28,622	39,034	45,497	46,542	48,985
	7 Jilin	11,917	15,762	18,737	19,377	20,491
	8 Heilongjiang	17,845	23,085	28,132	29,602	31,336
	9 Shanghai	17,308	24,458	23,131	26,338	27,952
	10 Jiangsu	17,136	21,845	30,130	31,819	36,186
	11 Zhejiang	6,582	8,320	12,675	13,562	15,307
	12 Anhui	8,585	11,367	15,549	16,761	18,058
	13 Fujian	4,111	5,117	6,745	7,381	8,271
	14 Jiangxi	6,056	7,660	10,676	11,755	12,418
	15 Shandong	19,612	25,532	32,717	35,432	40,749
	16 Henan	19,486	24,717	31,890	33,093	35,037
	17 Hubei	12,368	16,348	20,570	22,458	24,326
	18 Hunan	13,237	16,319	21,391	21,740	23,102
	19 Guangdong	8,832	11,319	15,413	17,224	19,916
	20 Guangxi	4,735	5,818	6,984	7,663	8,743
	21 Sichuan	20,362	25,837	32,893	34,754	37,745
	22 Guizhou	5,287	6,611	8,820	9,444	11,233
	23 Yunnan	5,441	6,796	9,279	9,500	10,838
	24 Tibet	68	81	105	119	103
	25 Shaanxi	7,690	9,788	13,104	14,149	15,443
	26 Gansu	4,981	6,283	9,182	9,563	10,073
	27 Qinghai	1,586	2,020	2,659	3,012	3,234
	28 Ningxia	1,571	1,963	2,833	3,286	4,015
	29 Xinjiang	4,936	6,201	8,506	8,610	8,831
	China Total	317,031	413,480	519,636	550,984	596,205
By States of India	1 Assam, etc.	1,403	1,646	1,852	1,943	2,049
	2 Bihar, etc.	16,690	22,463	23,535	23,050	23,459
	3 Orissa	5,813	3,062	3,292	3,134	3,146
	4 Andhra Pradesh	3,770	4,925	7,711	8,045	8,585
	5 Tamil Nadu, etc.	4,347	5,286	10,071	10,450	10,918
	6 Karnataka, etc.	4,116	4,926	5,944	6,081	6,381
	7 Maharashtra, etc.	9,743	13,687	17,744	18,860	20,324
	8 Madhya Pradesh	5,240	6,738	11,644	11,828	12,505
	9 Gujarat	5,793	8,019	13,012	13,741	14,503
	10 Rajasthan	2,271	2,820	3,829	3,905	4,035
	11 Uttar Pradesh, etc.	7,873	9,283	13,967	14,645	15,849
	12 Haryana, etc.	2,960	4,215	7,674	7,943	8,471
	13 Jammu, Kashmir	175	196	244	255	284
	India Total	70,194	87,268	120,520	123,879	130,507

⑤ In the share of the CO_2 emission (excluding vegetal fuels) by sectors in Asia as a whole, the industrial sector accounted for the largest share as with SOx and NOx emissions, though it had decreased its share from 41% in 1975 to 37% in 1987. The electricity generation sector had increased its share from 22% in 1975 to 25% in 1987. These two sectors accounted for 63% in 1975 and 62% in 1987 of the total. " The other " sector and the transportation sector remained at 17% and 11% respectively showing no remarkable changes between 1975 and 1987. The amount of CO_2 emission showed the highest rate of increase at 4.9%, exceeding the 3.9% average annual rate of increase for the total. In the share including vegetal fuels, " the other " sector expanded its share up to 30% in 1987 (See Figure-44 and Table-18).

⑥ The rate of the amount of the CO_2 emission per amount of primary energy consumption (including vegetal fuels) in Asian countries was approximately at the same level, but was slightly lower in the countries highly dependent on gas if vegetal fuels were included. If vegetal fuels were excluded, however, the amount of the CO_2 emission per unit of energy consumption in South Asian and Southeast Asian countries who were heavily dependent on vegetal fuels turned out to be small. This clearly indicates that, in order to limit the CO_2 emission, there are only two options: to limit the energy consumption or to make the re-fixation of CO_2

⑦ In the relation of the CO_2 emission per GDP with the economic improvement (GDP per capita), the amount of the CO_2 emission had been on the decrease as GDP per capita increased if vegetal fuels were included, and it reached to the maximum when the GDP per capita became 1,000 to 2,000 dollars if vegetal fuels were excluded. Also, in the process of industrialization, the CO_2 emission increased for some time (See Figure-46).

Fig. 40. Amount of CO2 emissions in Asia by countries



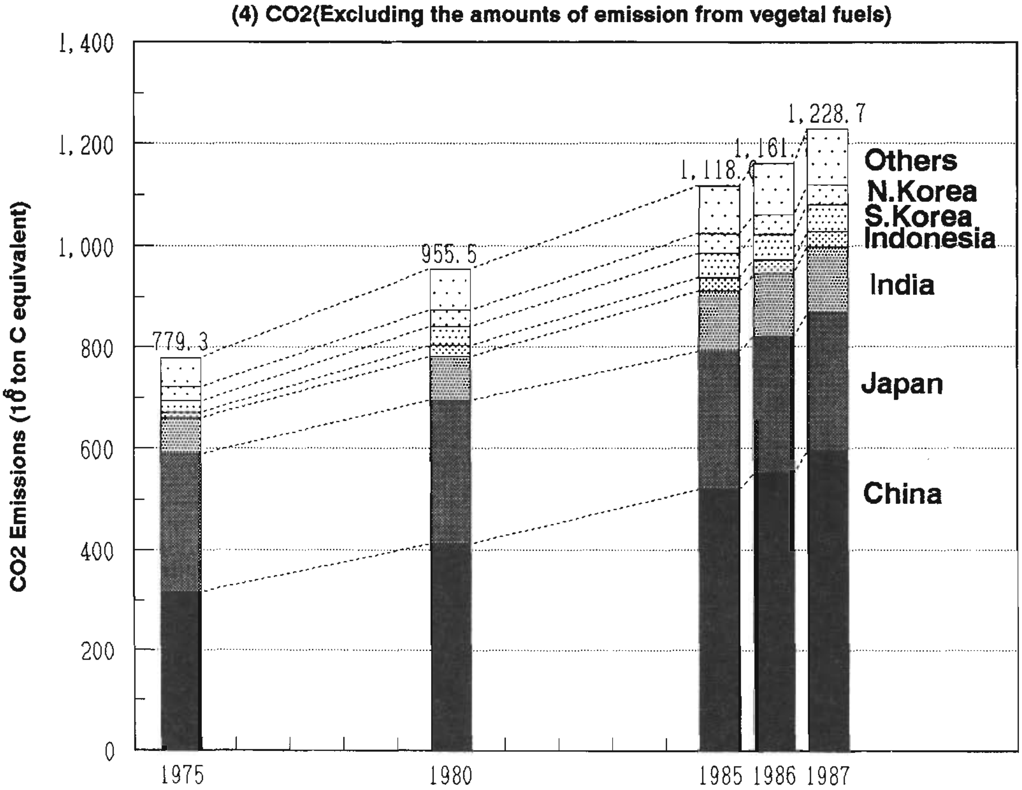
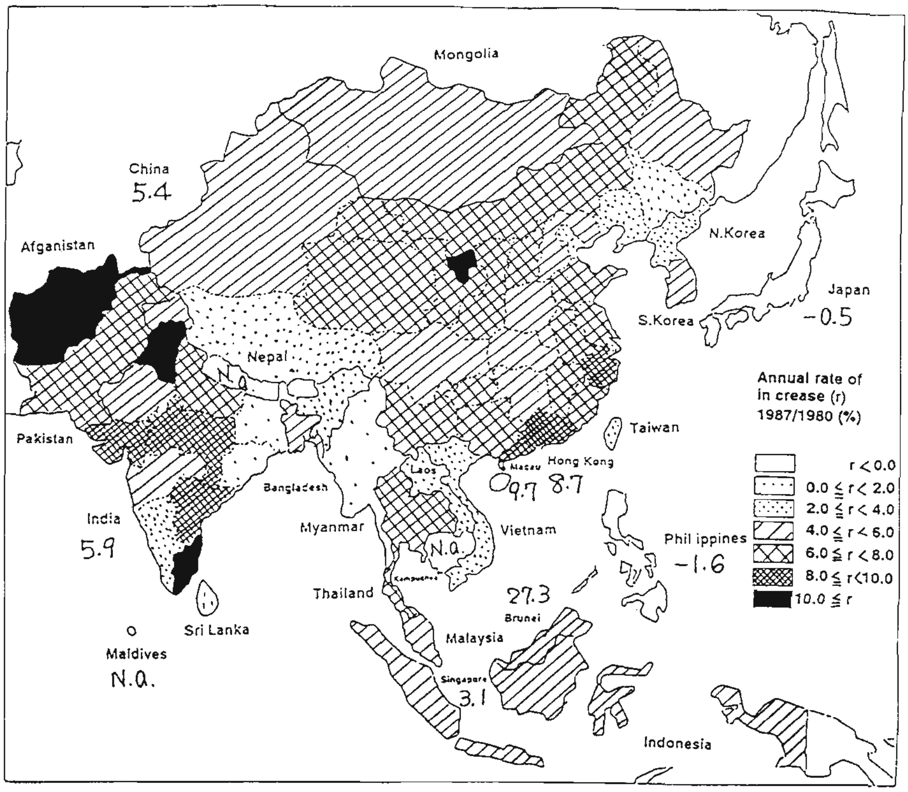


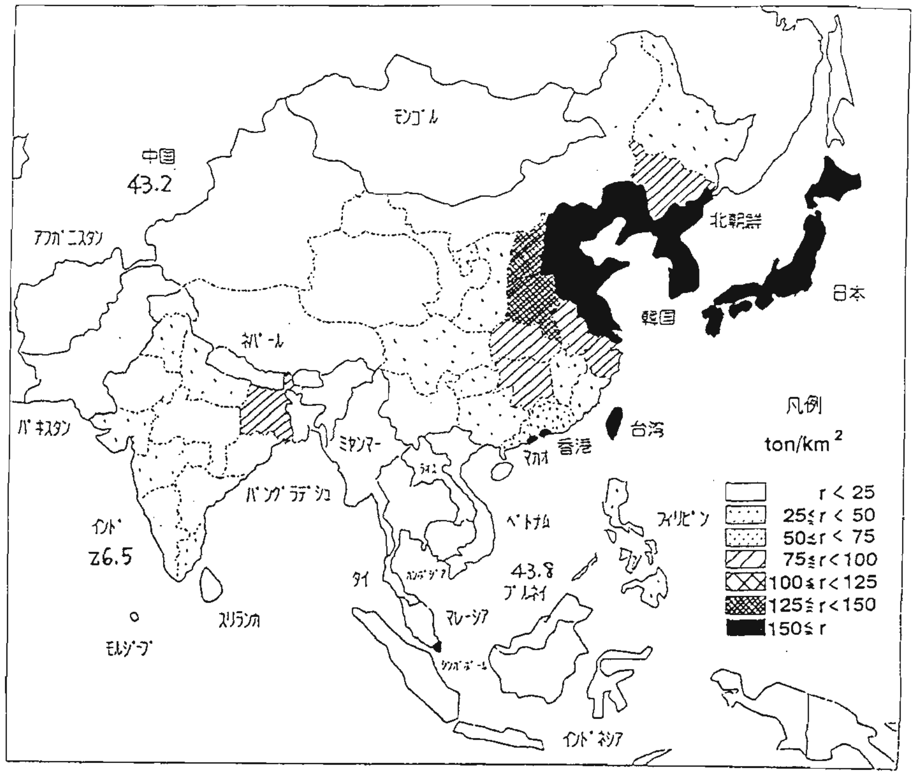
Fig. 41. Geographical Distributions of the Average Growth Rate (1987/'80) of the CO2 Emissions in the Asian Region



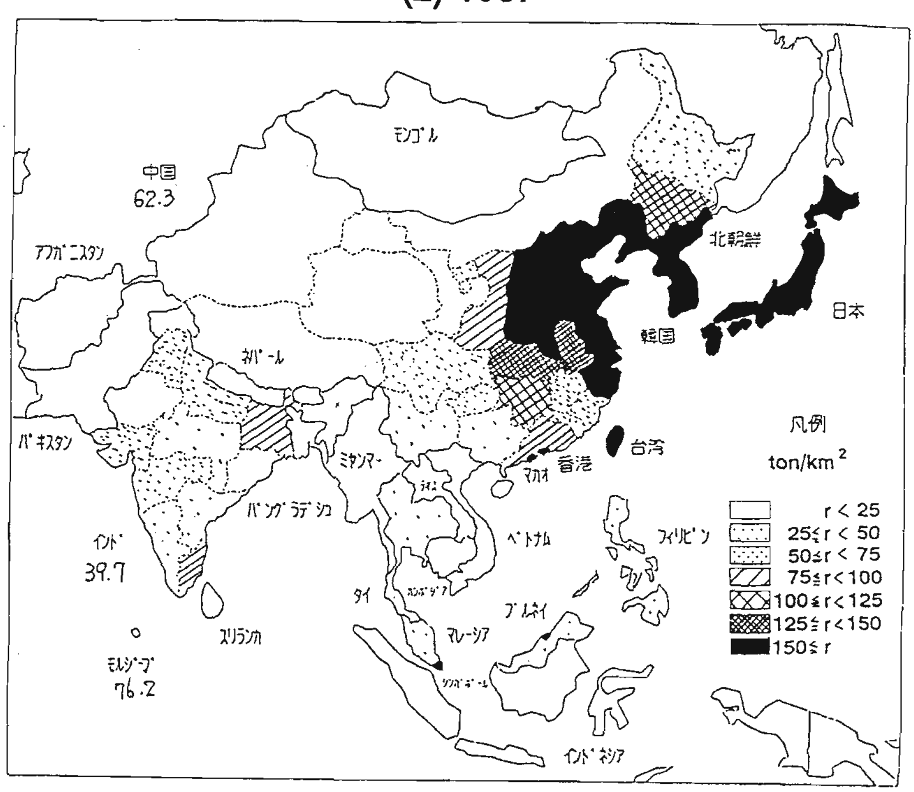
Excluding the amount of CO2 emission from vegetal fuels

Fig. 42. Geographical Distributions of the CO2 Emissions per Unit of Area in the Asian Region

(1) 1980



(2) 1987



Note: C equivalent.
Excluding the amounts of CO2 emission from vegetal fuels.

Fig. 43. CO2 emissions by energy sources: Asia

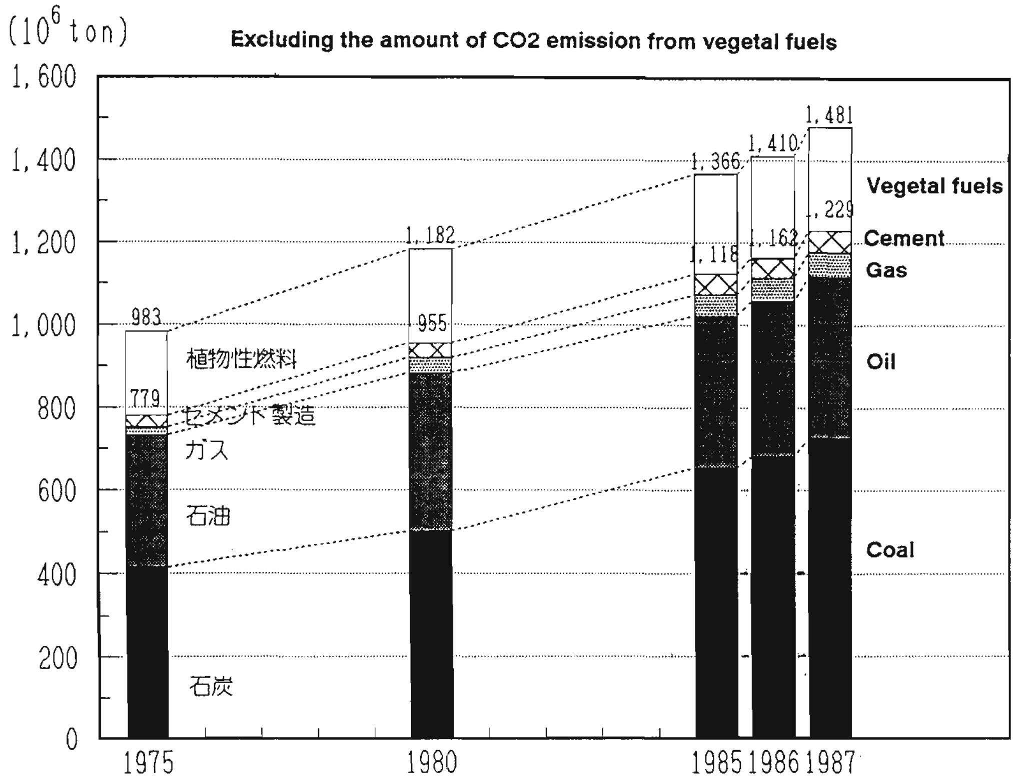


Table 17. CO2 Emissions by Energy Sources: Asia

	Year	Fossil Fuels				Vegetal Fuels	Energy Sector Total	Cement	Total
		Coal	Oil	Gas	Sub-Total				
Amount of Emissions (1,000 t)	1975	415,758	317,449	18,228	751,435	203,314	954,749	27,862	982,611
	1980	501,390	380,361	36,995	918,744	226,894	1,145,639	36,748	1,182,387
	1985	655,996	365,335	51,395	1,072,725	241,851	1,314,576	45,266	1,359,841
	1986	681,933	375,962	55,004	1,112,898	248,653	1,361,551	48,775	1,410,326
	1987	726,263	390,150	59,861	1,176,274	252,328	1,428,602	52,403	1,481,004
Conposition Ratio (%)	1975	42.3	32.3	1.9	76.5	20.7	97.2	2.8	100.0
	1980	42.4	32.2	3.1	77.7	19.2	96.9	3.1	100.0
	1985	48.2	26.9	3.8	78.9	17.8	96.7	3.3	100.0
	1986	48.4	26.7	3.9	78.9	17.6	96.5	3.5	100.0
	1987	49.0	26.3	4.0	79.4	17.0	96.5	3.5	100.0
Average Annual Rates of Increase (%)	75-80	3.8	3.7	15.2	4.1	2.2	3.7	5.7	3.8
	80-85	5.5	-0.8	6.8	3.1	1.3	2.8	4.3	2.8
	85-87	5.2	3.3	7.9	4.7	2.1	4.2	7.6	4.4
	80-87	5.4	0.4	7.1	3.6	1.5	3.2	5.2	3.3
	75-87	4.8	1.7	10.4	3.8	1.8	3.4	5.4	3.5

Fig. 44. CO2 emissions by sectors: Asia

Excluding the amount of CO2 emission from vegetal fuels

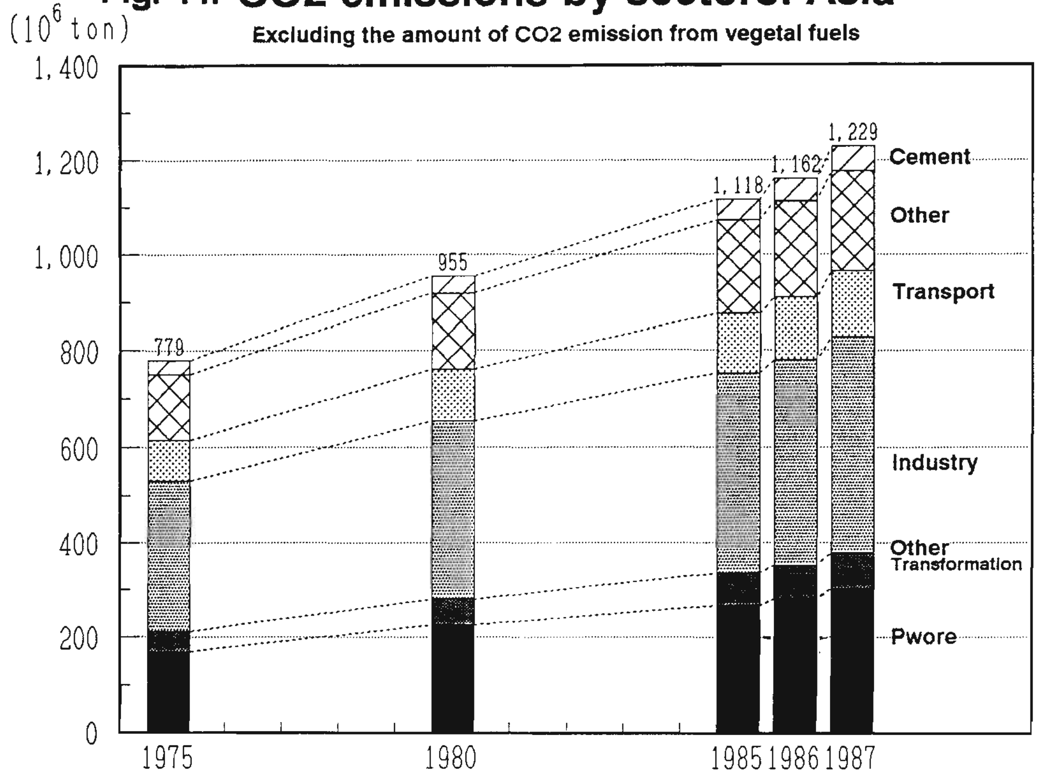


Table 18. CO2 Emissions by Energy Consumption Sectors: Asia

(1) Including Emissions from Vegetal Fuels

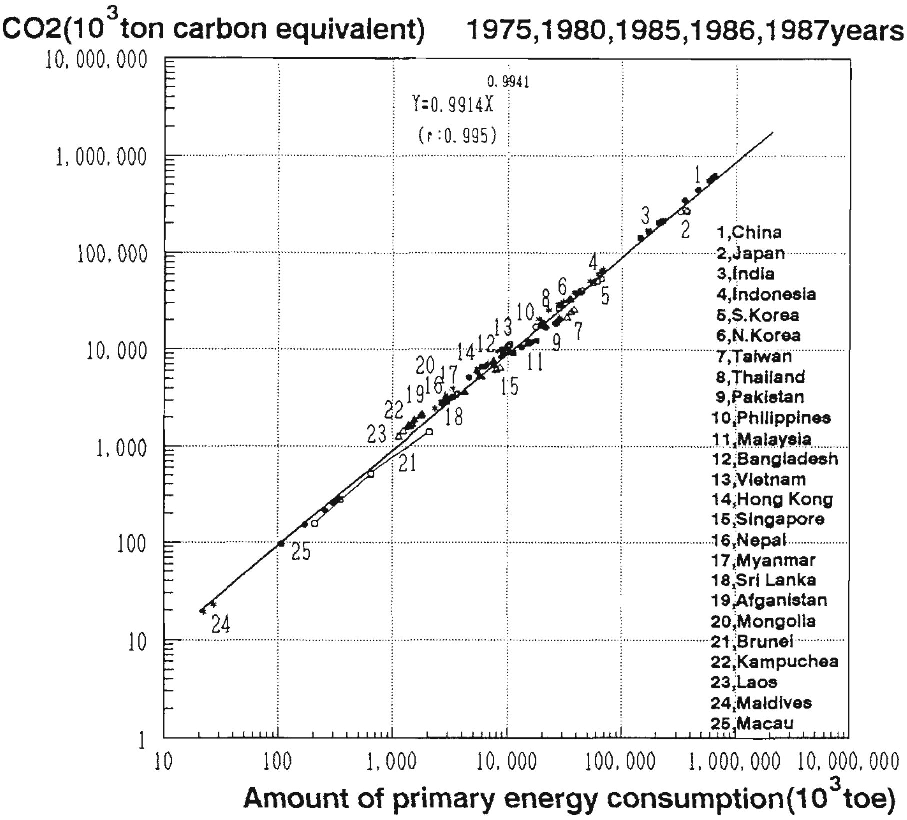
	Year	Transformation Sectors			Final Energy Comsunption Sectors					Energy Sector Total	Cement	Total
			Electric Generat.	Others		Industry	Transport	(Road)	Others			
Amount of Emissions (1,000 t)	1975	219,738	169,928	49,810	735,009	324,805	85,287	53,105	324,917	954,748	27,862	982,610
	1980	289,532	225,179	64,353	856,107	381,418	106,142	71,577	368,546	1,145,639	36,748	1,182,387
	1985	344,138	267,002	77,135	970,437	427,216	123,527	87,547	419,694	1,314,575	45,266	1,359,841
	1986	360,923	281,937	78,986	1,000,627	438,291	130,099	93,164	432,237	1,361,550	48,775	1,410,325
	1987	384,639	302,606	82,033	1,043,963	461,380	138,382	100,301	444,200	1,428,602	52,403	1,481,004
Conposition Ratio (%)	1975	22.4	17.3	5.1	74.8	33.1	8.7	5.4	33.1	97.2	2.8	100.0
	1980	24.5	19.0	5.4	72.4	32.3	9.0	6.1	31.2	96.9	3.1	100.0
	1985	25.3	19.6	5.7	71.4	31.4	9.1	6.4	30.9	96.7	3.3	100.0
	1986	25.6	20.0	5.6	71.0	31.1	9.2	6.6	30.6	96.5	3.5	100.0
	1987	26.0	20.4	5.5	70.5	31.2	9.3	6.8	30.0	96.5	3.5	100.0
Average Annual Rates of Increase (%)	75-80	5.7	5.8	5.3	3.1	3.3	4.5	6.2	2.6	3.7	5.7	3.8
	80-85	3.5	3.5	3.7	2.5	2.3	3.1	4.1	2.6	2.8	4.3	2.8
	85-87	5.7	6.5	3.1	3.7	3.9	5.8	7.0	2.9	4.2	7.6	4.4
	80-87	4.1	4.3	3.5	2.9	2.8	3.9	4.9	2.7	3.2	5.2	3.3
	75-87	4.8	4.9	4.2	3.0	3.0	4.1	5.4	2.6	3.4	5.4	3.5

(2) Excluding Emissions from Vegetal Fuels

	Year	Transformation Sectors			Final Energy Comsunption Sectors					Energy Sector Total	Cement	Total
			Electric Generat.	Others		Industry	Transport	(Road)	Others			
Amount of Emissions (1,000 t)	1975	213,016	169,928	43,088	538,418	317,963	85,287	53,105	135,168	751,435	27,862	779,297
	1980	280,721	225,179	55,542	638,024	373,594	106,142	71,577	158,288	918,744	36,748	955,492
	1985	335,532	267,002	68,530	737,193	417,151	123,527	87,547	196,514	1,072,725	45,266	1,117,990
	1986	352,418	281,937	70,481	760,480	427,305	130,099	93,164	203,076	1,112,898	48,775	1,161,673
	1987	377,044	302,606	74,438	799,230	450,505	138,382	100,301	210,342	1,176,274	52,403	1,228,676
Conposition Ratio (%)	1975	27.3	21.8	5.5	69.1	40.8	10.9	6.8	17.3	96.4	3.6	100.0
	1980	29.4	23.6	5.8	66.8	39.1	11.1	7.5	16.6	96.2	3.8	100.0
	1985	30.0	23.9	6.1	65.9	37.3	11.0	7.8	17.6	96.0	4.0	100.0
	1986	30.3	24.3	6.1	65.5	36.8	11.2	8.0	17.5	95.8	4.2	100.0
	1987	30.7	24.6	6.1	65.0	36.7	11.3	8.2	17.1	95.7	4.3	100.0
Average Annual Rates of Increase (%)	75-80	5.7	5.8	5.2	3.5	3.3	4.5	6.2	3.2	4.1	5.7	4.2
	80-85	3.6	3.5	4.3	2.9	2.2	3.1	4.1	4.4	3.1	4.3	3.2
	85-87	6.0	6.5	4.2	4.1	3.9	5.8	7.0	3.5	4.7	7.6	4.8
	80-87	4.3	4.3	4.3	3.3	2.7	3.9	4.9	4.1	3.6	5.2	3.7
	75-87	4.9	4.9	4.7	3.3	2.9	4.1	5.4	3.8	3.8	5.4	3.9

Fig. 45. CO2 emission related to the amounts of the primary energy consumption: Asian countries

(1) Including the amounts of CO2 emission from vegetal fuels.



(2) Excluding the amounts of CO2 emission from vegetal fuels.

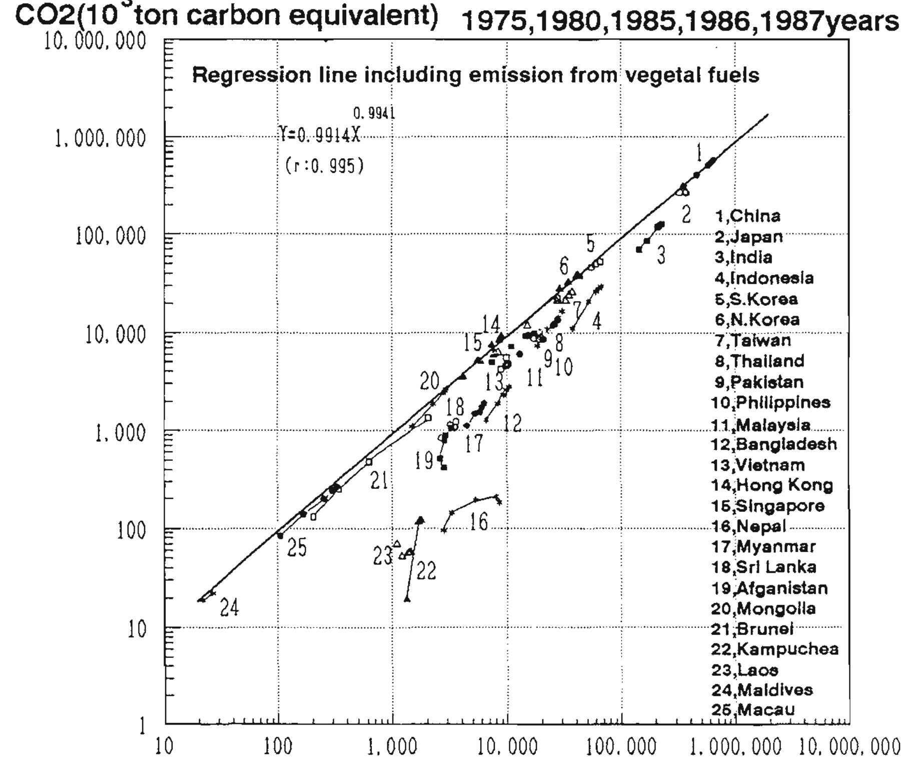
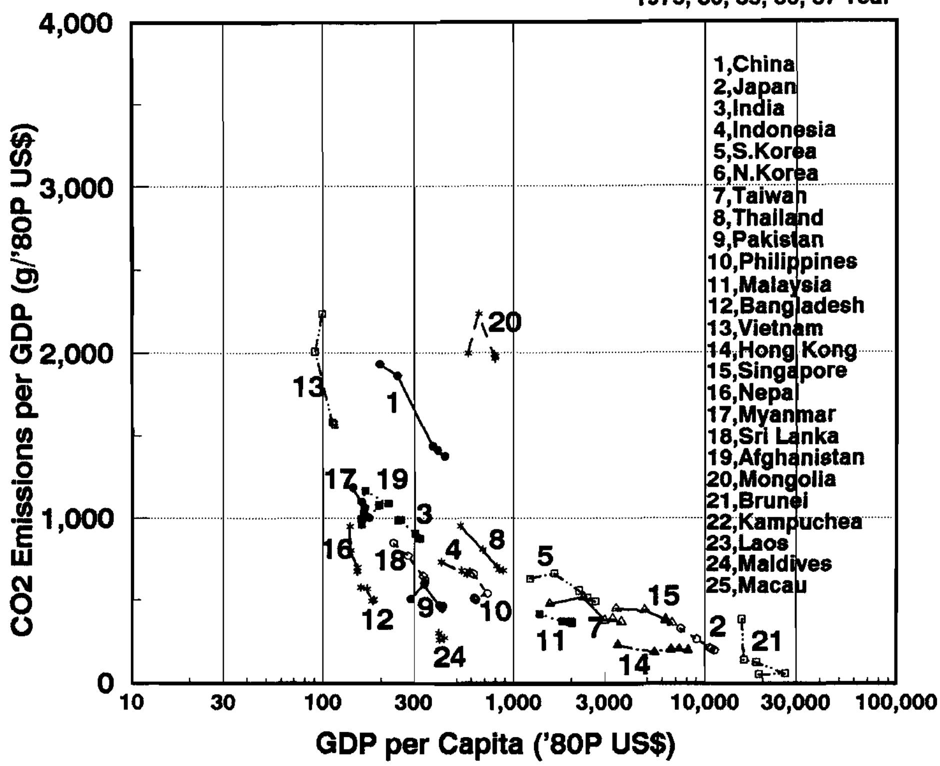


Fig. 46. Relations between Economic Levels and CO2 Emissions per GDP Asian Countries

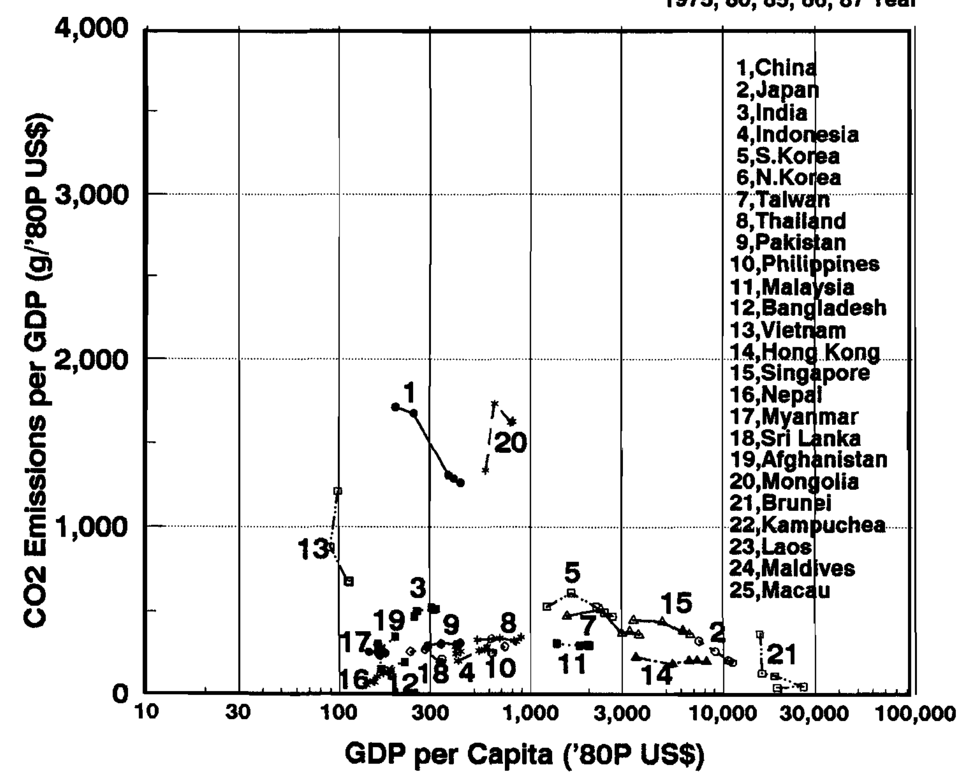
Including Emissions from Vegetal Fuels

1975,'80,'85,'86,'87 Year



Excluding Emissions from Vegetal Fuels

1975,'80,'85,'86,'87 Year



IV. Conclusion

In this study, the energy structure in the whole region of 25 Asian countries is reviewed.
This includes vegetal fuels, an important energy source in developing countries, coal, oil, natural gas, etc.

Also, with respect to sulfur contents of fuels as a basis for an estimate of the amount of the SOx emission, particularly those in China and India, the data and information are obtained through our field consultations, etc. (China: Chinese Central Coal Distribution Corporation, etc., India: Coal Bureau of Energy Department). Furthermore, emission factors for NOx, suitable especially for the situation in developing countries, are set up by 17 sectors and 25 kinds of fuels on various assumptions. CO_2 emission factors are also surveyed by 27 kinds of fuels. On the basis of these results, the amounts of the SOx, NOx, and CO_2 emission in 25 Asian countries and in the disricts of China and India by sector and energy source are reviewed for the first time, with the trends in the period between 1975 and 1987. The results of the survey are summarized in the following sections.

1. Economic Developments and the Resulting Changes in the Energy Consumption Structure and the Effect on the Environment in the Asian Region

(1) The Situation in the Asian Region Where the Growth Rate of the Energy Demand and its Potential in the Future are Higher Than Any Other Part of the World

In the period between 1975 and 1987, the Asian region recorded the highest growth rate of GDP in the 8 regions of the world (the average annual growth rate at 5.3%), and in accordance with this, primary energy consumption increased on an average annual growth rate of 3.8%, or the energy intensity of 0.7, and amounted to 1.62 million toe (ton oil equivalent) in 1987 from 1.04 billion toe in 1975. As a result, the share of GDP in the world expanded from13% to 17%, and that of primary energy consumption from 17% to 20%. Nevertheless, as energy consumption per capita in the Asian region, which accounts for 57% of the world population, is the lowest in the world, the region has a huge potential for the growth of energy consumption.

On a country-by-country basis in Asia, higher than the average growth rates were witnessed in the NIEs, China and ASEAN countries. The primary energy intensities for GDP were around 1.0 in these countries, except China, Japan, etc. and developing countries, and the average annual rate of increase in the primary energy consumption were more than 6% in Asian NIEs, etc. and between 5 and 6% in China, India, etc.

Furthermore, with improvements in economic levels (GDP per capita), energy consumption per capita is also increasing in these countries fellowing a course similar to Japan and Singapore.

(2) Shifts of Dependency from Vegetal Fuels to Fossil Fuels and from Oil to Coal and Gas

In the meantime, this region, reflecting the difference in economic conditions in developed countries, Asian NIEs, centrally-planned economies, and developing countries, and in the reserves of energy sources, has shown several characteristics in the primary energy consumption by source under the economic growth pursued in coping with the two oil crises.

One of these characteristics was a decrease in the growth rate of oil consumption and increasing dependence on coal, gas, and nuclear power. In particular, consumption of coal exceeded that of oil in 1981, and coal captured the largest share in the energy sources in Asia increasing from 37% in 1975 to 43% in 1987, and this made Asia the only region in the world in which coal had the largest share. Furthermore, the consumption of coal in Asia was the largest in the world in 1984 exceedind that of U.S.S.R.-East European region, accounting for 32% of the world coal consumption in 1987. Also, another characteristic of the Asian region was high dependence on vegetal fuels, accounting for 38% of the world vegetal fuel consumption in 1987.

In the share of energy sources by country, the share of fossil fuels had been on the increase and that of vegetal fuels on the decrease in South Asia and Southeast Asian countries. In Japan, South Korea, and Taiwan, etc., the share of nuclear powered primary electricity (nuclear power) had been on the increase, substituting for that of fossil fuels. In the case of fossil fuels, in order to decrease the share of oil, there were some countries shifting to gas like Malaysia, Bangladesh, Indonesia, etc., other countries shfting to coal like NIEs, China, etc., and still some countries other than these two extremes shifting to both coal and gas like

Japan and Thailand. Particularly, the increase in coal consumption in China has contributed much to the total coal consumption in Asian region.

As the consumption of vegetal fuels has a close relation to the economic level (GDP per capita), the share of vegetal fuels in the primary energy consumption began to decrease as GDP per capita increased, and became zero at around 3,000 dollars (1980 U. S. dollar).

(3) A Shift in the System of Energy Use toward Industrialization and Electrification Taking Place with the Improvement in the Economuc Levels and the Propagation of the System to East Asia, Southeast Asia and South Asia

In the final energy consumption sector (the industrial, transportation, and " the other " sectors), with the improvement in the economic level (GDP per capita), the share of " the other " sector had been on the decrease, and the share of the industrial sector and even that of the transportation sector had been on the increase. In particular, in " the other " sector consisting mainly of residential use, the share was the highest in South Asia where the income was low and was lower in Southeast Asia and the NIEs in this order, and became the lowest when the GDP per capita attained about 8,000 dollars (1980 U. S. dollar). Beyond this level, it became higher again as witnessed in Japan and Brunei.

Except the transportation sector, trends in sources of energy consumption , as in the primary energy consumption, showed a shift from vegetal fuels to fossil fuels, and from fossil fuels to electricity consumption with the improvement of the economic level. Especially in the rate of electrification (the total electricity consumption in the total final energy consumption), Nepal, Myanmar, Bangladesh, etc. were low at less than 4%, becaming higher in the order of South Asian low-income countries, ASEAN countries in Southeast Asia, Asian NIEs, and finally Japan and Brunei with more than 20%. Thus, improvement in the standard of living is expected to increase the rate of electrification, then, in turn, the demand for the increase of the electricity generation capacity. In particular, the trend for the increasing rate of electrification as witnessed in Southeast Asia and Brunei in South Asia indicates a potential for a considerable increase in the energy demand in the future.

(4) Worsening Air Pollution with the Increase of the Energy Consumption and the Delayed Measures

Air pollution among Asian countries is witnessed in the northern part of China and cities in South Korea where heating is needed in winter time; large cities in Southeast Asia, India and Pakistan where the number of unfixed cars is increasing rapidly; cities in NIEs where industrialization is rapidly developing and automobiles are on the increase in number, and large cities in Japan where air pollution resulting from automobile exhaust gas emission is worsening, though the regulation on such emissions have been implemented.

As for concentrations of SOx, which were relatively well monitored, there were many cities which exceeded guidelines of WHO in China, South Korea, India, and Hong Kong. Especially in cities in the coastal area of China and New Delhi in India, air pollution was worsening with the rapid progress of the SOx concentration in recent years.
In the meantime, acid rains with pH between 4 and 5 have appeared in Japan, South Korea and China, and in particular it has become a serious problem in Guizhou and Sichuan Provinces in China.

In these countries, measures are mainly for soot and, though South Korea and Taiwan lowered the sulfur level of fuels, they are not yet sufficient except in Japan, and environmental measures will be much in need corresponding to the increase in the energy demand in the future.

2. Efficiency of Energy Use by Stage of the Economic Development in the Asian Region

(1) Promotion of Energy-Efficient Industrialization in Developing Countries

A considerable increase in the energy demand is expected with the economic development in Asian countries. Thus, not to speak of the resulting tight energy supply and demand situation, it is necessary to push on with efficient use of energy in order to lessen the load on the global environment. If the size of the economy and the efficiency of energy use are expressed in terms of the amount of the energy consumption per GDP, it became smaller as the economic levels (GDP per capita) are improved, as shown in the order of a trend in South Asia, Southeast Asia, NIEs, and Japan. But in the industrialization process, as experienced in Japan and NIEs, enrgy consumption per GDP tended to become larger, thus it is important for developing countries to plan energy-efficient industrialization programs based on these experiences.

(2) A Wide Gap in Energy Efficiency in the Electricity Generation Sector

With respect to energy sources input into the elecricity generation sector, India, Indonesia, etc. had increased the share of fossil fuels; Nepal, the Philippines, etc. had increased the share of hydraulic power; and South Korea , Taiwan and Japan had increased the share of nuclear power, and, in this way, there are countries who are pursuing the use of coal and gas away from oil in the mix of fossil fuels.

In electricity generation efficiency, compared to the high rate of nearly 40% in Japan, there are some countries at less than 30%, and, since the efficiency is lower in developing countries, it is important to improve the efficiency of energy use in view of the increase in the electricity demand. The same is true of the rate of total loss (a total of in-plant consumption and transmission losses), which becames higher in the order of Japan, NIEs, ASEAN countries, and South Asian countries with the highest,and it is necessary to improve the efficiency as in the case of the electricity generation efficiency.

3. Trends in the Amount of the SOx, NOx, and CO_2 Emissions in the Asian Region

(1) Increasing Dependence on Coal and the Increase in the Amount of the SOx, NOx, and CO_2 Emissions Exceeding the Increase in Energy Consumption in the Asian Region

The average annual growth rates of the SOx, NOx, and CO_2 emissions (from 1975 to 1987) in the Asian region as a whole were 3.9%, 4.3%, and 3.9% respectively, exceeding the 3.8% average annual growth rate of primary energy consumption (See Table-19). The primary reason for exceeding the average annual growth rate of primary energy consumption was that the dependence on coal in the Asian region as a whole had been increased. In particular, the SOx emission showed a marked increase though environmental measures and fuel conversion to gas had been implemented in Japan, South Korea, Taiwan, etc. This was primarily because, against the 3.8% average annual growth rate of primary energy consumption between 1975 and 1987, the SOx emission increased at 5.9%,due mostly to the high share of China who had been more and more dependent on coal.

In the share of the amount of the SOx, NOx, and CO_2 emissions by energy source in the Asian region as a whole, emission from coal accounted for 60 to 70%, and thus share showed a rapid increase between 1975 and 1987. This was the result of the increasing dependence on coal in the Asian region as a whole.

Table 19. Amounts of SOx, NOx, CO2 emissions and average annual rates of increase of these

	Year	Asia Total		OECD Countries		World	
		Emissions (M t)	Rates (%)	Emissions (M t)	Rates (%)	Emissions (M t)	Rates (%)
SOx	1975	18.3		57.9			
	1987	29.1	3.9	*42.2	-3.1		
NOx	1975	9.4		34.7			
	1987	15.5	4.3	36.2	0.4		
CO2	1975	779.3		2,674.6		4,811.5	
	1987	1,228.7	3.9	2,868.2	0.6	6,080.8	2.0

* : 1985 value. CO2: carbon equivalent

Source) OECD Countries and World by [OECD: OECD ENVIRONMENTAL DATA COMPENDIUM 1991]

(2) Loads on the Global Environment in East Asia with Increasing Dependence on Coal and Loads on the Global Environment in South Asia and Southeast Asia with High Dependenve on Vegetal Fuels and Natural Gas in the Diversity of Energy Supply

In order to stabilize the energy supply after the experiences of the two oil crises, it is vital for every country to implement a policy to diversify its energy supply away from energy use mainly consisting of oil. There are regional characteristics in China and East Asian countries like South Korea, Taiwan, Hong Kong, etc., where the dependence on coal which places a heavy load on the global environment had been on the increase. On the other hand, in South Asian and Southeast Asian countries like Bangladesh, Myanmar, Indonesia, Nepal, etc., the dependence on vegetal fuels and gas, which place relatively lighter loads on the global environment, was high. Particularly, these factors had a large impact on the difference in the amount of the SOx, NOx, and CO_2 emission per amount of primary energy consumption.

(3) The SOx, NOx, and CO_2 Emission Concentrated in East Asia and the High Growth Rates in China and Inland Areas in India

Out of the total amount of the SOx, NOx, and CO_2 emission in Asia as a whole, the largest 6 countries including China, Japan, India, South Korea, etc. accounted for about 90% of all of the SOx, NOx, and SO_2 emissions. In particular, China was the largest emitter, increasing its share to 69% in SOx, 48% in NOx, and 49% in CO_2 in 1987.

Also, the amount of the SOx, NOx, and CO_2 emissions per unit of area in the Asian region including those by district in China and India (1985 and 1987) was high in East Asia and NIEs, and the area with the high emission had been expanding yearly.

Further, the average annual growth rate of the amount of the SOx, NOx, and CO_2 emissions (from 1975 to 1987) was high for all of the SOx, NOx, and CO_2 emissions in the coastal areas in China, reflecting the industrial activities, and in the central part of India and the inland area in China became of the influence of the installation of electricity generation plants for the purpose of electrification of these areas.

(4) The Increasing Amount of SOx, NOx, and CO_2 Emissions in Accordance with the Electrification

In the share of the SOx, NOx, and CO_2 emissions by sector in the Asian region as a whole, it had been on the increase in the electricity generation sector and on the decrease in the industrial sector. These two sectors accounted for 60 to 70% of the share of all of the SOx, NOx, and CO_2 emissions. In the NOx emission, the transportation sector accounted for a relatively high share at about 25% of the total NOx emission. It should be noted that in the future the electricity generation sector will make a larger contribution to all of the SOx, NOx, and CO_2 emissions by sector as a result of the electrification in progress. Also, as for NOx, it is expected to grow considerably in the transportation sector in accordance with the increase in the number of automobiles.

(5) The Dependence on Vegetal Fuels in Asian Region; Possibly the Highest in the World

The amount of consumption of vegetal fuels in the Asian region is the largest among the 8 regions in the world, and the dependence on vegetal fuels is particularly high in South Asian and Southeast Asian countries. Vegetal fuels emit CO_2 when consumed, but the CO_2 emitted from the consumption is considered to be restabilized to the extent that they are used without destroyting forests. As the economic levels were improved, however, the dependence on fossil fuels tended to be on the increase.

4. Relations between Stage of Economic Developments and the Amount of SOx, NOx, and CO_2 Emissions

In Asian region, especially in the developing countries, the amount of the SOx, NOx, and CO_2 emissions was increasing with the increase of energy consumption in accordance with the economic growth. The trend in the relation between the economic level (GDP per capita) and the amount of the SOx emission per GDP in Asian countries was an increase in the amount of the emission as GDP per capita increased. It had a tendency to reach the maximum at 1,000 to 2,000 dollars of GDP per capita and decrease thereafter as GDP per capita became larger. This was because the dependence on fossil fuels became higher, substituting for vegetal fuels as the economic levels improved. Also, in the relation between the amount of the NOx emission per GDP and the economic level, the amount of the NOx emission per GDP tended to decrease as GDP per capita increased. As for CO_2 , with the increase in the GDP per capita, the amount of the CO_2 emission per GDP tended to be on the decrease, as in the case of NOx, if the emission from vegetal fuels were included. If the emission from vegetal fuels were excluded, it reached a maximum of 1,000 to 2,000 dollars of GDP per capita as in the case of SOx.

Since in the process of industrialization at the stage of improving levels of the economy, all the amounts of the SOx, NOx, and CO_2 emissions per GDP had a tendency to grow for some time, as in the case of energy consumption per GDP, it is important for developing countries to take environmental factors into consideration during their industrialization.

In the industrialized countries, reduction measurs for SOx had been taken in Japan, South Korea, Taiwan, etc. and for NOx in Japan through environmental measures, and these efforts had been reflected considerably in the reduction of the emission per GDP.

V. Issues in the future

1. Establishment of an Energy Related Data Base

(1) The Need for Establishment of an Energy-Related Data Base in Developing Countries in Particular

In order to implement measures for the global environment relating to the use of energy, it is necessary particularly for developing countries to establish an energy- related database which has high reliablity and details on the types of industry. Based on this, it would be easier not only to design environmental policies, but also to implement international transfer of energy conservation technologies by type of industry, etc.

(2) The Need for Establishment of a Database for Fuel Properties from the Viewpoint of the Preservation of the Global Environment

Fuel properties in the existing database (e. g. calories) are primarily for use in supply-demand balance, but it is necessary to establish a database for sulfur, nitrogen, and carbon contents of fuels by district of production in view of the preservation of the global environment.

2. Necessity for Technological Developments Suitable for the Asian Region under the Limitation of Energy and the Environment

In the Asian region, it is expected that the limitations of energy and the environment would be tightened in accordance with the increasing demand for energy under the growing depedence on fossil fuels and away from vegetal fuels. In particular, under the limitation of energy, it would be inevitable from a long range viewpoint to depend more and more on coal, which places larger loads on the global environment among fossil fuels, ahead of the other regions in the world. Under the circumstances, it is necessary to develop technologies under the limitations of energy and the environment based on the characteristics of the Asian region.

(1) Pursuit of Suitable Energy Use for the Situations in the Region and Developments of Technologies of Environmental Measures

It is necessary to use energies such as coal, oil, gas, hydraulic power , nuclear power, renewable energies, etc. in a suitable way for the circumstances in each country and pursue further development of technologies for the environmental presrvation suitable for the circumstances in each country with the initiatives of developed countries.

(2) The Electricity Generation Sector under the Progress of Electrification Particularly in Need of the Global Environment Preservation Measures

In the Asian region where the demand for coal, which places larger loads on the global environment, is expected to grow further, it is necessary to implement thoroughgoing measures taking the environmental problems into consideration. In particular, the amount of the emission of substances which would affect the global environment from the electricity generation sector is increasing, and thus the environmental measures in this sector, especially in the use of coal, is the most important issue.

(3) Necessity for Improvements in the Efficiency of Energy Use

In the industrialization pursued during current stages of economic development in developing countries, it is particularly necessary to improve the efficiency of energy use. Also, energy efficiency (generation efficiency and the rate of loss) was remrkably low in developing countries, and thus the improvement of efficiency is the most important issue in view of rapid electrification.

(4) Necessity for Development of Low-cost Technologies for Environmental Measures

It is highly possible that the impact of the increasing use of coal in China and India would aggravate not only pollutions in their countries, but also the global acidification and green house effect. In reality, however GDP per capita in China and India, were too small to accomodate sufficient funds for environmental measures. It is important to pursue cost-effective environmental measures which are most suitable for these countries.

(5) Necessity for Establishment of a Total System for Improvements in Energy Efficiency

As witnessed in the heat supply system from electricity generation plants to cities in China, it is necessary to establish a total system for improving energy efficiency adapting to the local climate and geographical conditions.

(6) Necessity for Reassessment of Vegetal Fuels

Since the Asian region was the largest consumer of vegetal fuels in the world, it is necessary to pursue policies for the utilization of these fuels, taking the preservation of forest into consideration, and coping with the increasing dependence on fossil fuels in accordance with the improvement in the economic level.

3. Land-Use Plans in the Asian Region from a Global Viewpoint Taking the Preservation of the Global Environment into Consideration and the Necessity for International Cooperation Schemes

In the review of global environmental measures, it is necessary to make a review not only on a world regional or a country-by- country basis, but on the basis of detailed bottom-up approach as attempted in this study by dividing districts within China and India. Under the circumstances, it is necessary to establish a standpoint for land-use plans for the Asian region as a whole in the pursuit of the preservation of the global environment and international cooperation schemes to implement these plans.

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