6.4.3 International Comparison

In this chapter, the correlations among primary energy consumption, GDP, and emissions of SOx, NOx and CO_2 in Asian countries and developed countries are examined. Then, the present status of those of I.R. Iran is reviewed in comparison with the above correlations.

The results of the comparisons are shown in the APPENDIX, and graphical presentations are shown in Figure 6.30 through Figure 6.32. On these figures, the shift which I.R. Iran and Japan made from 1975 to 1987 is traced using arrows.

The data on which the comparison is based were prepared in the following manner.

1) Data on I.R. Iran

The primary energy consumption and the emission volumes of SOx, NOx and CO_2 for the whole of I.R. Iran are based on the energy balance table that is provided in the APPENDIX and the emission factors that is described in 6.4.1. In the APPENDIX, the primary energy consumption and the emission volumes of SOx, NOx and CO_2 for Tehran province and Tehran city are calculated on the basis of the emission volume per capita and the population of the province and the city. The GDP value is converted into the constant price for 1980. The conversion is based on the data on "Parameter Table for Emission Estimation" in the APPENDIX.

2) Data on Asian Countries

The primary energy consumption including vegetative fuel, and the emission volume of SOx, NOx and CO_2 are taken from "Energy and Global Environmental Problems in Asia" (Science and Technology Agency, Japan). The emission factors used in the report are provided in the APPENDIX. The GDP value is converted into the constant price for 1980. 'TOTAL ASIA' on the table in the APPENDIX represents the total value for 25 countries for 20 countries indicated on the table plus the values for Brunei, Cambodia, Laos, Mordives and Macao.

3) Developed Countries

In the APPENDIX, U.S.A., Canada, U.K., Netherlands, Sweden, Germany, France and Japan have been selected as developed countries. The environmental data for these countries is taken from "OECD Environmental Data 1993". The GDP value is converted into the constant price for 1980. The emission volumes of SOx, NOx and CO_2 in Japan are based on this information and the figures are slightly different from those shown on the table for Asian countries.

(1) Primary Energy Consumption and Emission of SOx, NOx and CO_2

Figure 6.33, Figure 6.34, Figure 6.35(a) and (b) show the relationships between primary energy consumption and the emission volumes of SOx, NOx, CO_2 in Asian countries. Each figure shows the volume of emission (thousand ton) on the vertical axis and primary energy consumption (thousand TOE) on the horizontal axis, both on a logarithmic scale.

A linear regression analysis on these two variables -- energy consumption and emission -- was conducted. The result of the regression is shown below.

SOx Emission	Ln(SOx)=-6.21 + 1.16 Ln(PEC)	R sqr.=0.918
NOx Emission	Ln(NOx)=-4.14 + 0.95 Ln(PEC)	R sqr.=0.987
CO_2* Emission	Ln(CO_2)= 0.01 + 0.99 Ln(PEC)	R sqr.=0.997

*: Carbon equivalent

(2) Economic Level (GDP) and Emission of SOx, NOx and CO_2

Figure 6.36, Figure 6.37, Figure 6.38 (a) and (b) show the relationships between the economic level (GDP per capita) and the emission volumes of SOx, NOx, CO_2 per GDP in Asian countries. The emission volume per unit GDP represents economic efficiency from the viewpoint of pollutant emission. A small value of this index indicates a high economic efficiency.
The emission of SOx and NOx decreases when the economy depends mainly on primary electricity (hydraulic electricity, etc.), vegetative fuel and natural gas. On the other hand, the emission of CO_2 is stimulated by a dependency on vegetative fuel.

According to Figure 6.36, SOx emission increases along proportionate to economic growth, or GDP per capita in Asian developing countries. This tendency continues until the GDP per capita reaches the level of $1,000 to $2,000. The trend is reversed when the GDP per capita grows beyond this level. This phenomena can be explained with the following steps.

a) 1st stage

As the economy grows, the energy source shifts from vegetative fuel, which is a small contributor to SOx emission, to fossil fuels which encourage the emission. The shift increases SOx emission per GDP.

b) 2nd stage

The SOx emission per GDP increases further together with the industrialization of the country.

c) 3rd stage

It can be said that energy intensity, or energy consumption per GDP, decreases as GDP per capita increases beyond a certain level. This tendency leads to decreased SOx emission after the economy achieves a certain level of development. In addition to this, countermeasures against air pollution can further decrease SOx emission, like in the case of Japan, Korea and Taiwan.

As shown in Figure 6.37, NOx emission per GDP decreases as the economy grows. However, it is difficult to trace such similar trends as SOx emission per GDP for NOx emission as well.

Figure 6.38 (a) and Figure 6.38 (b) show CO_2 emission volumes in Asian countries. Figure 6.38 (a) shows the emission volume which includes vegetative fuel sources. Figure 6.38 (b) shows the emission volume that does not.

The CO_2 emission volume that includes (per GDP) vegetative fuel sources decreases along with economic growth. However, the CO_2 emission volume that excludes vegetative fuel sources shows a similar trend to what is indicated in the figure for SOx emission. In this case, CO_2 emission increases as GDP per capita increases up to the level of $1,000 to $3,000, and the trend is reversed as the economy grows beyond this level.

Fig. 6.30 SO_x Emission - Primary Energy Requirement

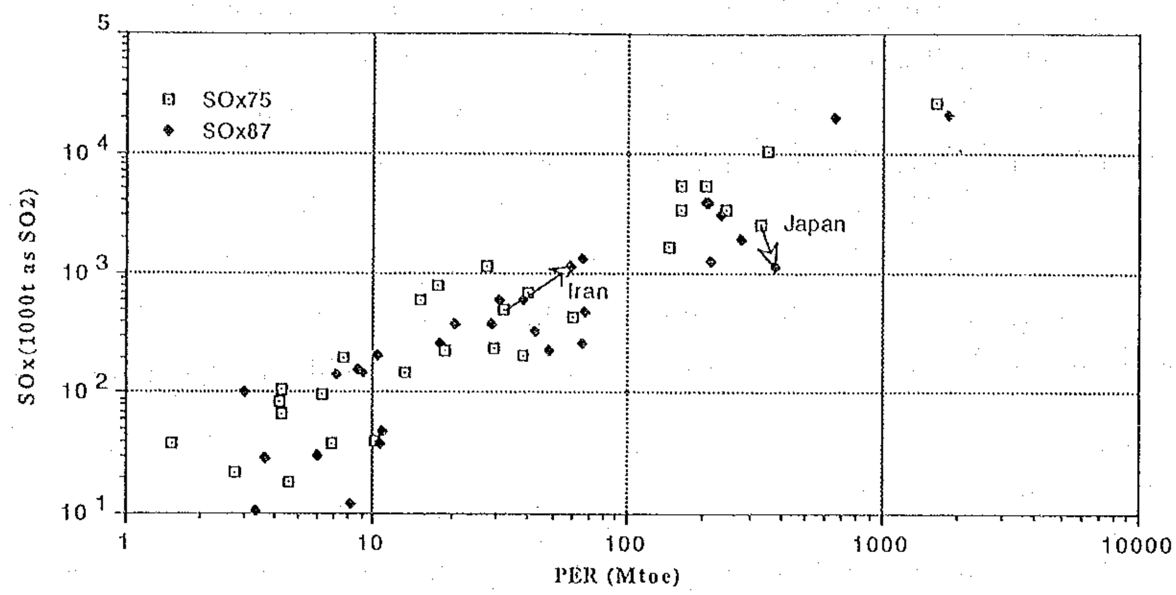


Fig. 6.31 NO_x Emission - Primary Energy Requirement

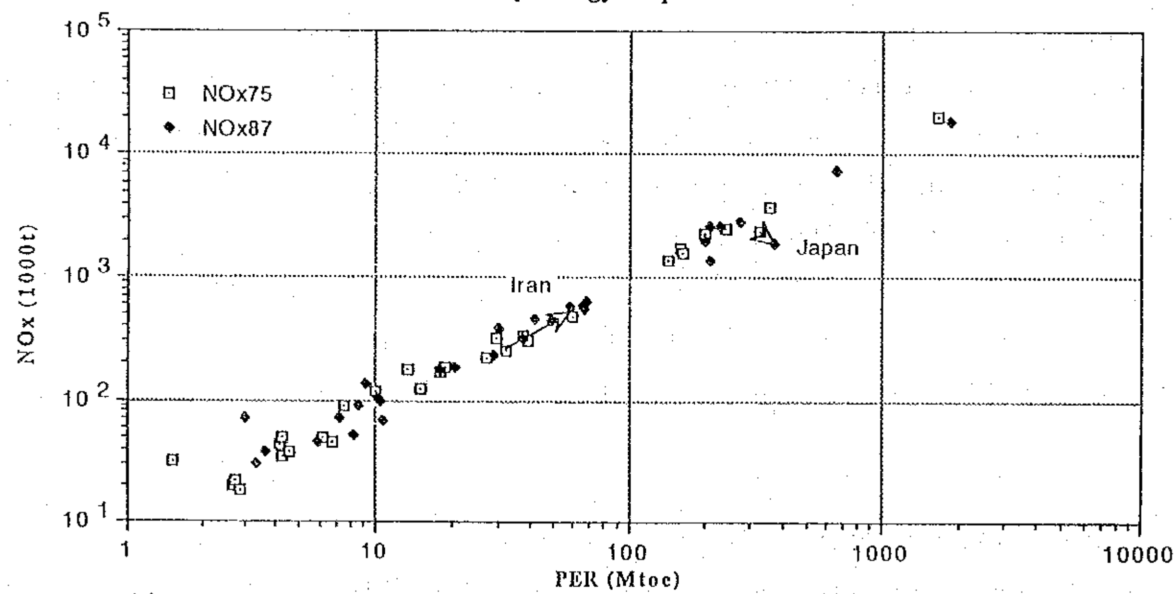


Fig. 6.32 CO_2 Emission - Primary Energy Requirement

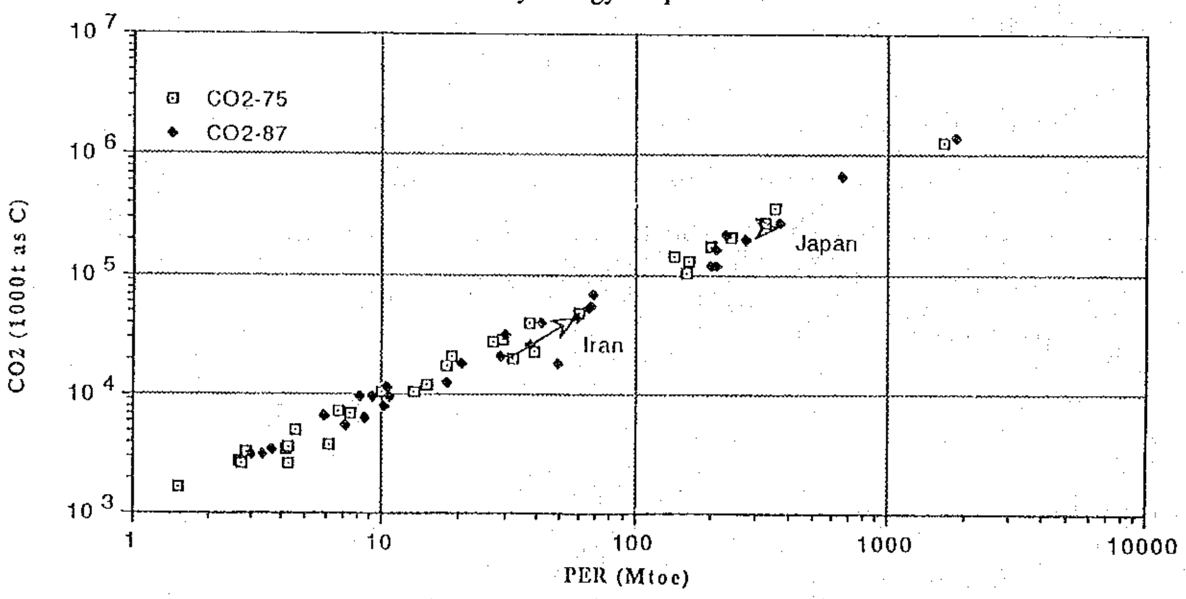


Fig. 6.33 SO_x Emission vs. Primary Energy Requirement

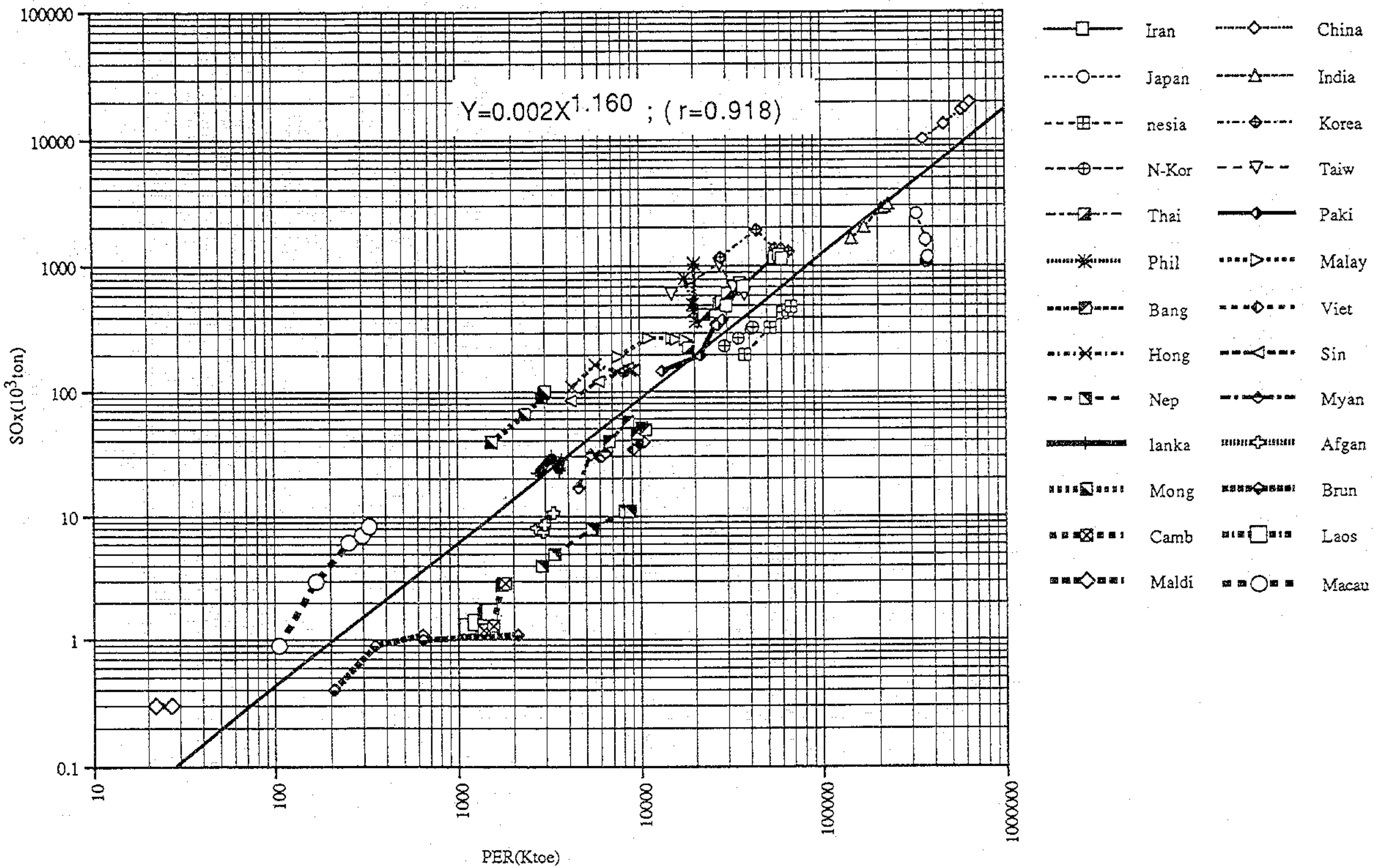


Fig. 6.34 NO_x Emission vs. Primary Energy Requirement

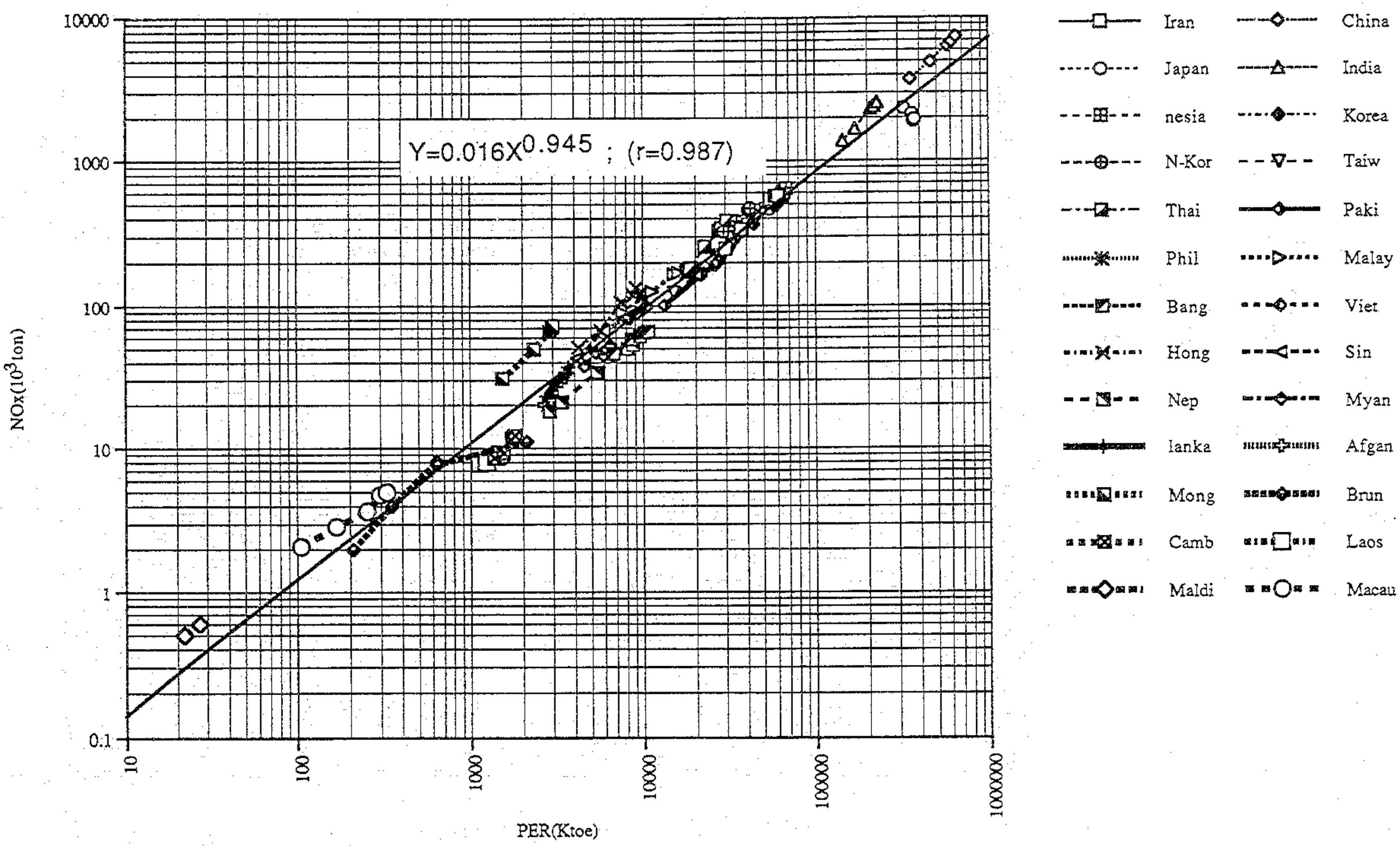


Fig. 6.35(a) CO_2 Emission vs. Primary Energy Requirement

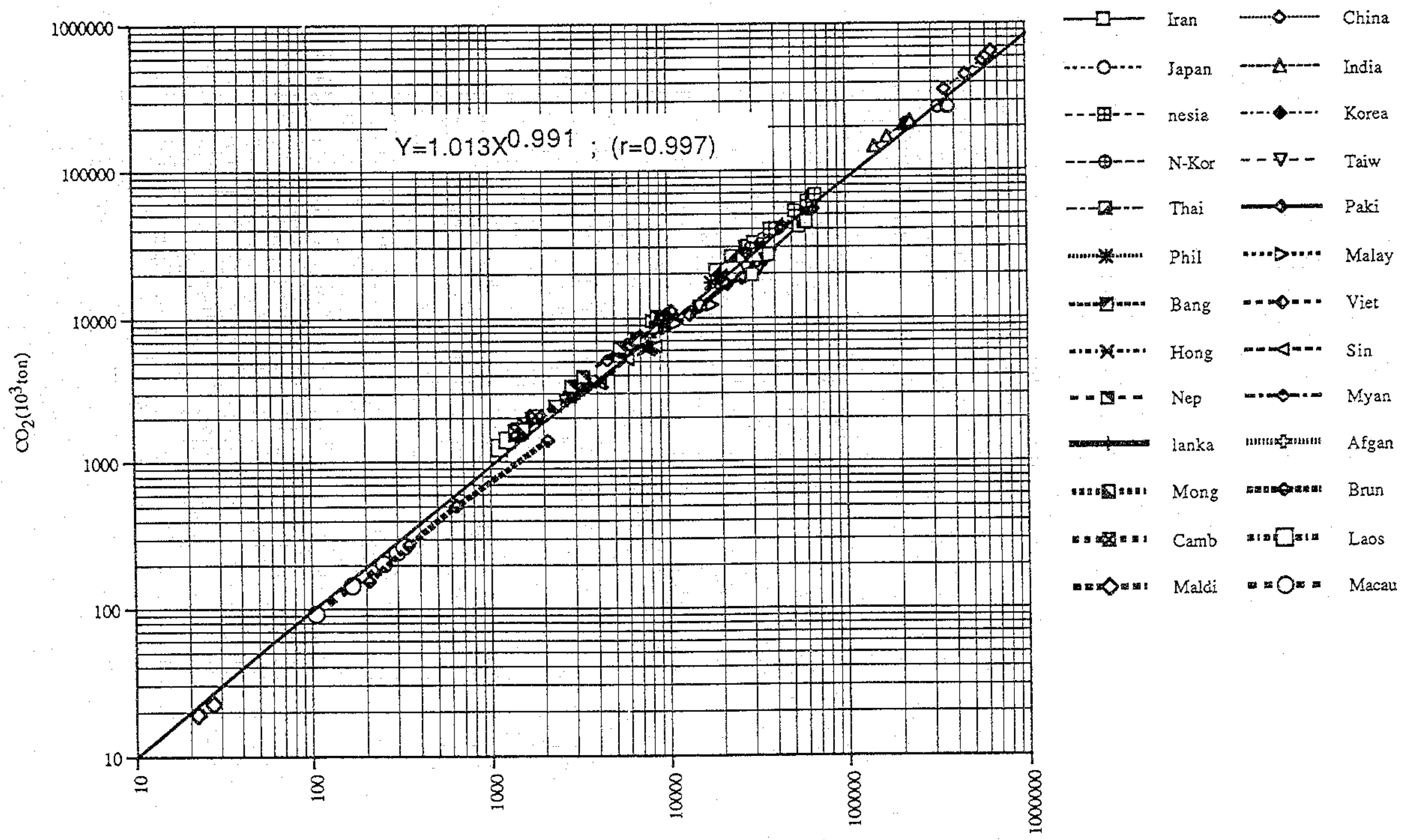


Fig. 6.35(b) CO_2 Emission vs. Primary Energy Requirement (Excludes Vegitative Fuel)

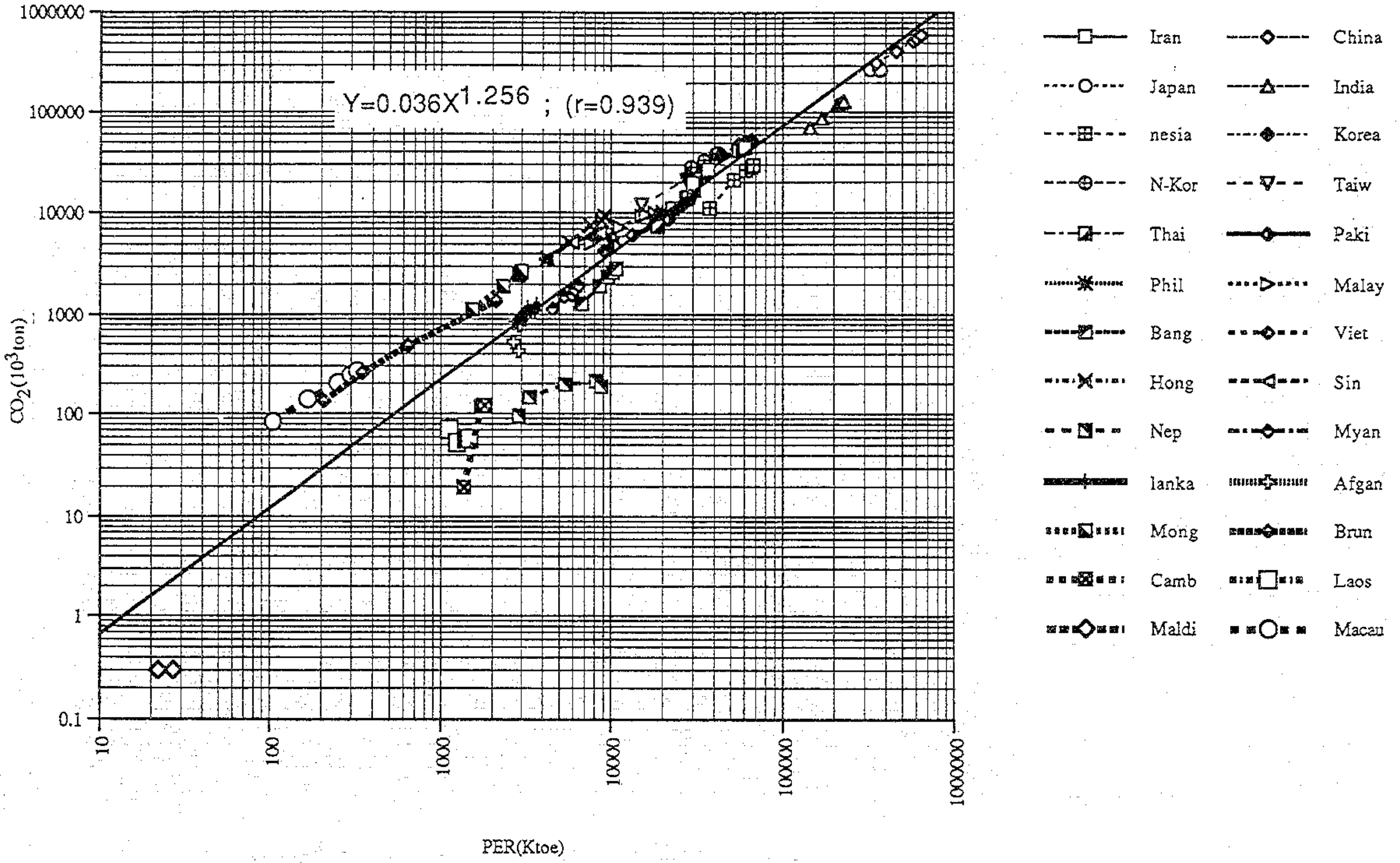
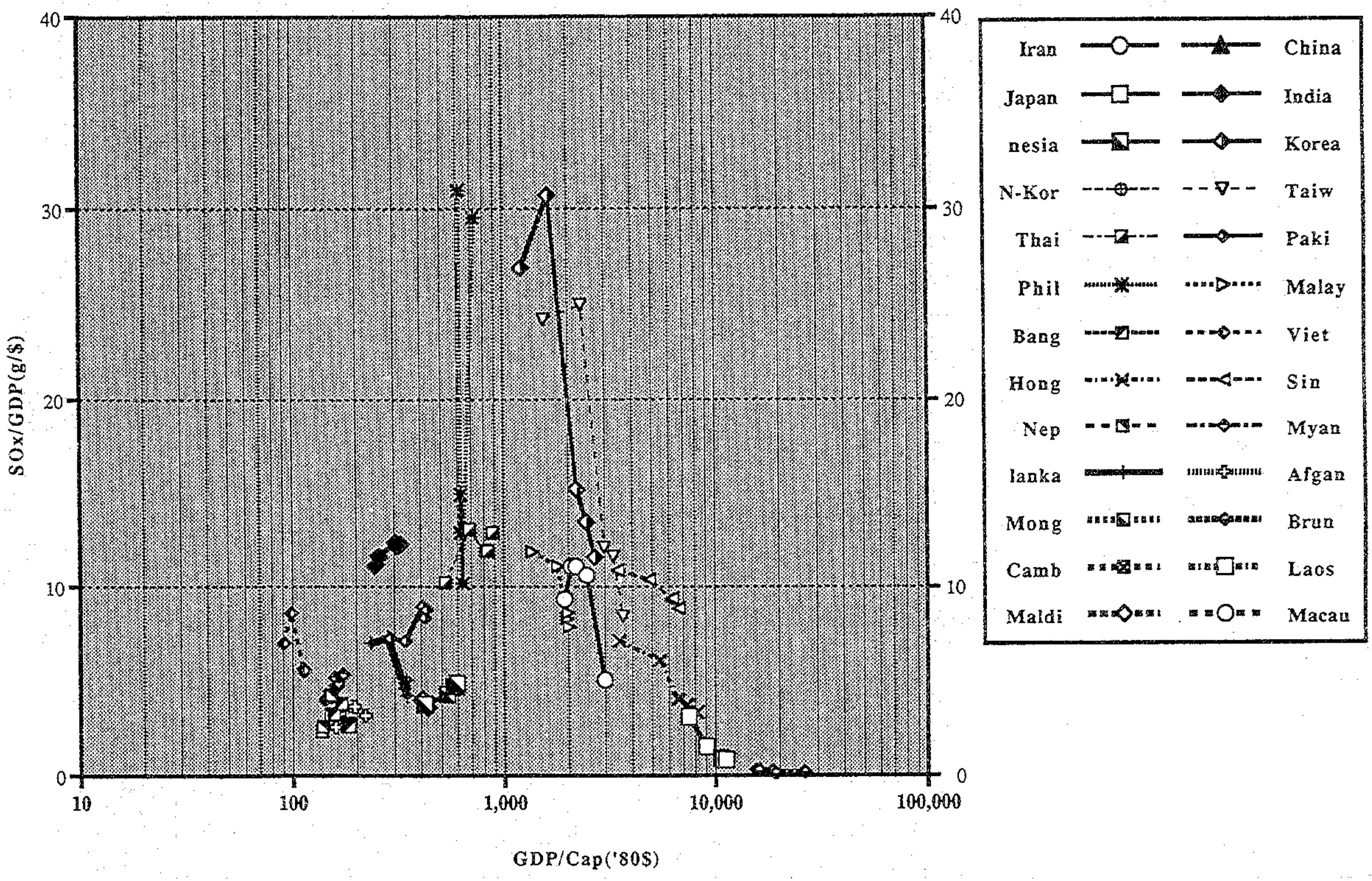
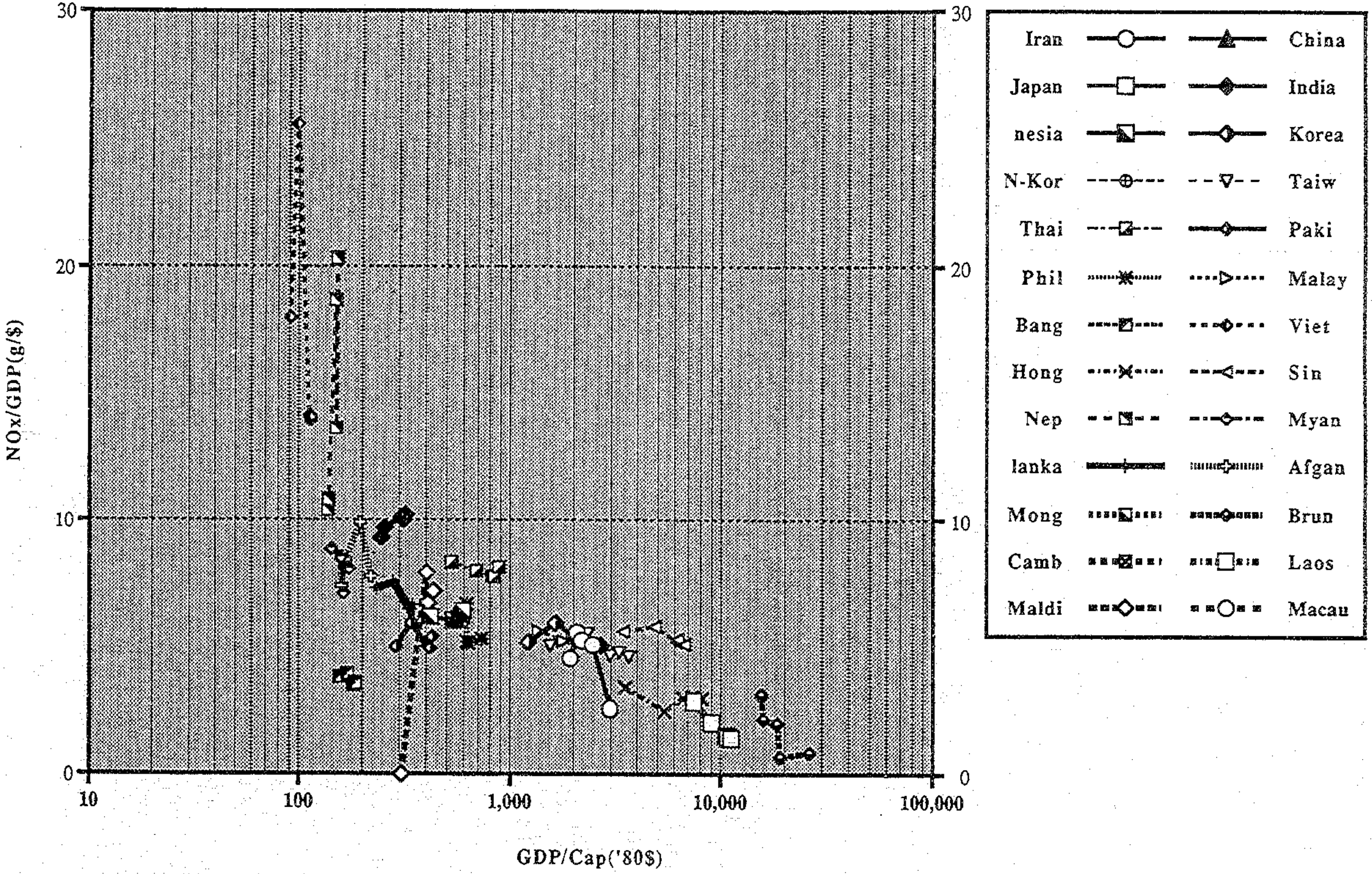


Fig. 6.36 SO_x / GDP : GDP / Capita



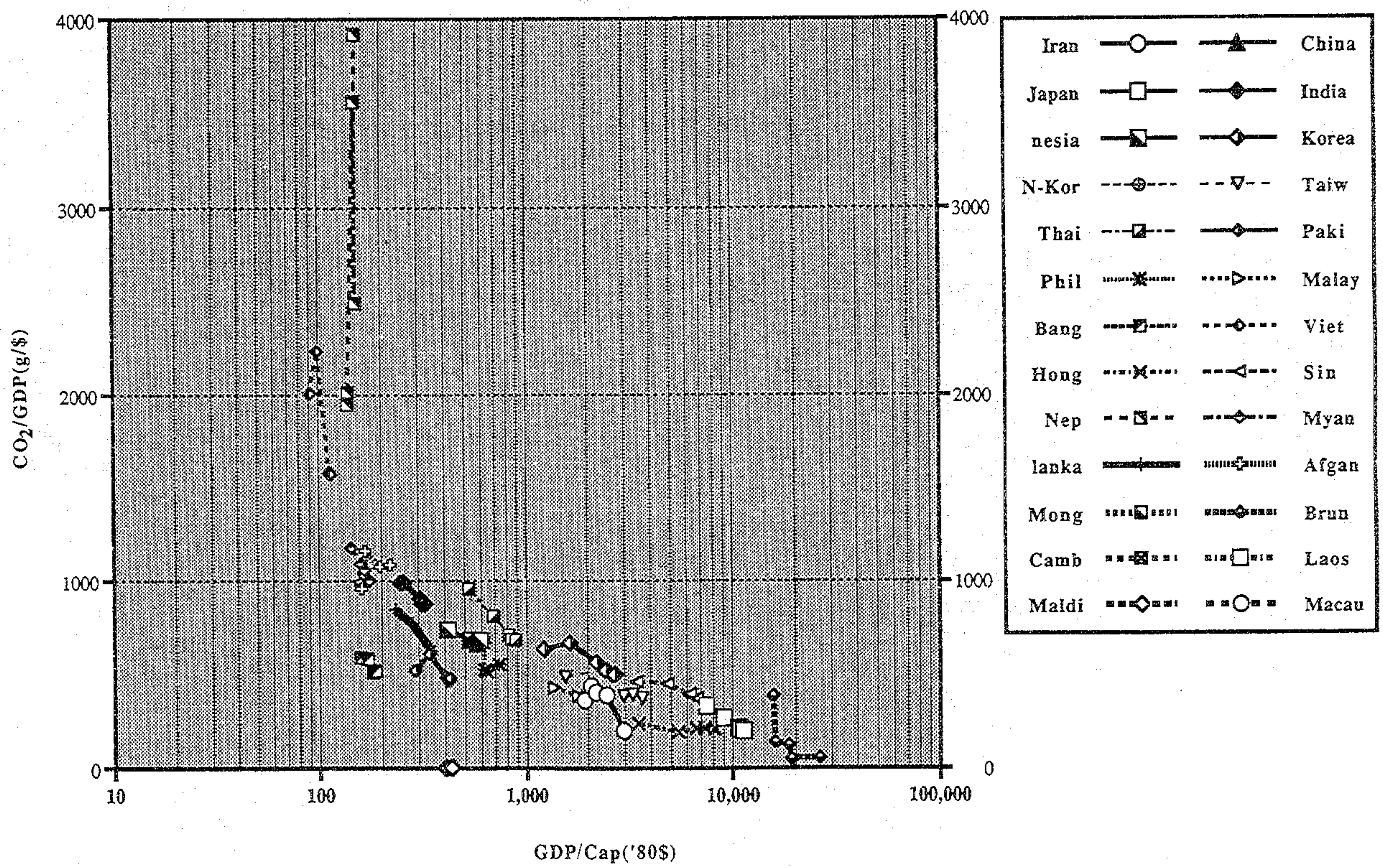
SOx Emission Volume per GDP and Per-capita GDP
(includes emission volume from vegitative fuels)

Fig. 6.37 NO_x / GDP : GDP / Capita



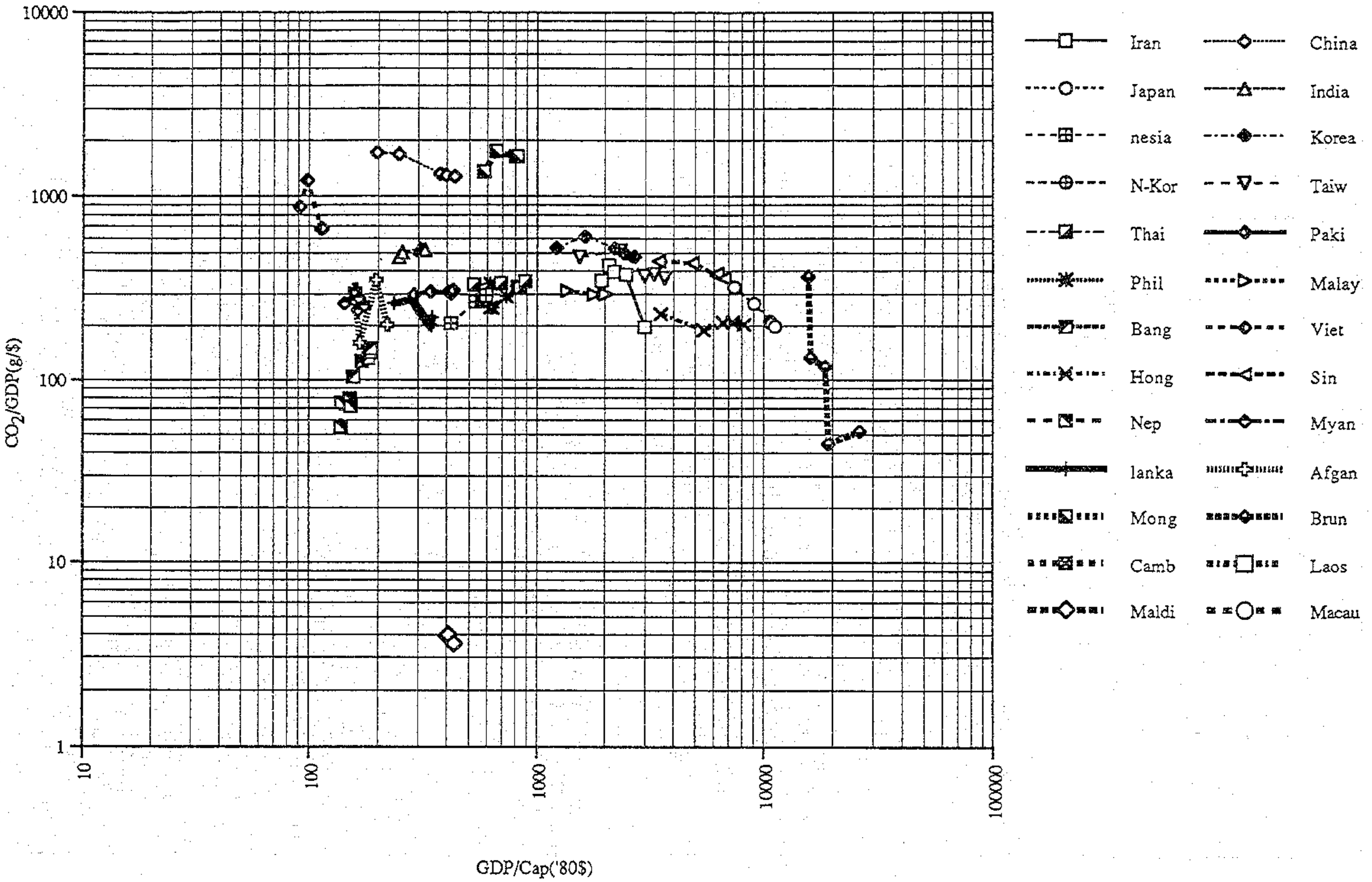
NOx Emission Volume per GDP and Per-capita GDP
(includes emission volume from vegitative fuels)

Fig. 6.38(a) CO_2 / GDP : GDP / Capita



CO2 Emission Volume per GDP and Per-capita GDP
(includes emission from vegitative fuels)

Fig. 6.38(b) CO_2 / GDP : GDP / Capita (Excludes Vegitative Fuel)



6.5 Forecast on Emission Volume

6.5.1 Emission Volume estimated by use of Energy Balance Table

The forecast of pollutant emission was made on the basis of the country's future energy balance estimated for 1990 to 2021 and the emission factors that have been used for the estimation of the country's emission history in section 6.4.1 of this report.

An estimation on future energy balance for 1990, 2001, 2011 and 2021 is shown in the APPENDIX. The estimation was conducted on the basis of the history of energy balance from 1968 to 1990. The estimation on final energy demand was divided into two categories -- by sector and by fuel type -- and is shown in Figures 6.39 and 6.40.

The emission factors used for calculating air pollutant (SOx and NOx) emission volumes and green-house-effect gas (CO_2) are shown in the APPENDIX.

(1) Energy Demand

1) Final Energy Demand by Sector

As shown in Figure 6.39, final energy demand is on a continuous up trend. The rise from the base year 1990 (=1.0) to the years 2001, 2011 and 2021 are 2.1, 3.2 and 3.8, respectively. The most serious increase is found in the transportation sector, where the rise from the base year 1990 (=1.0) to the years 2001, 2011 and 2021 are 2.7, 5.1 and 6.7. , respectively.

2) Final Energy Demand by Fuel Type

As shown in Figure 6.40, the most serious increases are found in the demand for electricity and gasoline. The rise from the base year 1990 (=1.0) to the years 2001, 2011 and 2021 in the demand for electricity and gasoline are 2.1 and 3.6, 5.2 and 2.7, 5.1 and 6.9, respectively. The share of gas in final energy demand does not show a significant increase. The rise from the base year 1990 (=1.0) to the year 2021 in the demand for natural gas is 2.5, while that for electricity and petroleum products are 5.2 and 4.5, respectively. However, the growth of natural gas demand in the conversion sector is remarkable. According to our estimate, the increase from the base year 1990 (=1.0) to the year 2021 in the demand for natural gas in the power generation sector is 7.6, while the increase in the demand for petroleum products is 3.6.

(2) Emission Volume

1) Emission Forecast by Sector

a) SOx

Figure 6.41 is a forecast of SOx emission by sector. SOx emission will increase with the rise in energy consumption. The increase of emission will be remarkable especially in the transportation and conversion sectors. The growth in industrial sector will not be so striking. The rise in total SOx emission from the base year 1990 (=1.0) to the years 2001, 2011 and 2021 are 2.0, 2.9 and 3.4, respectively. The increase in SOx emission in the transportation and conversion sectors from the base year 1990 (=1.0) to the years 2001, 2011 and 2021 are 2.7 5.1, 6.9 and 2.1, 3.2 and 3.4, respectively. The increase in the industrial sector in the same years are 1.5, 1.8, 1.8, respectively. The transportation and industrial sectors show drastic changes in the share of SOx emission. The transportation sector share increases from 17% of the total in 1990 to 35% in 2021. The industrial sector share decreases from 31% of the total in 1990 to 16% in 2021. According to the future energy balance table, SOx emission from the conversion sector will not increase as expected because the use of natural gas for power generation will become more widespread.

b) NOx

Figure 6.42 a forecast of NOx emission by sector. The total NOx emission is estimated to increase by 5.2 times from 1990 to 2021. The main cause of the growth is the rapid increase in emission in the transportation sector. The increase in total NOx emission in the transportation sector from the base year 1990 (=1.0) to the years 2001, 2011 and 2021 are 2.7, 5.1 and 6.9, respectively. The growth rates of gasoline and gas oil consumption in the transportation sector are estimated to remain at almost the same level during the period, according to the future energy balance table. For the share of NOx emission in total emission for each sector, the industrial and transportation sectors show radical changes. The share of NOx emission for the industrial sector will decrease from 12%

in 1990 to 4% in 2021. The transportation sector will increase its share from 55% in 1990 to 73% in 2021.

c) CO_2

Figure 6.43 is a forecast of CO_2 emission by sector. The total emission volume of CO_2 will increase in line with the increase in energy consumption. Total CO_2 emission in 2021 is estimated to be 3.9 times that in 1990. Power generation in the conversion and transportation sectors show a radical increase. The increase in total CO_2 emission in the power generation and transportation sectors from the base year 1990 (=1.0) to the years 2001, 2011 and 2021 are 2.4 and 3.7, 5.1 and 2.7, 5.1 and 6.9, respectively. The transportation sector also expands its share of CO2 emission. It will grow from 21% in 1990 to 37% in 2021.

2) Emission by Type of Fuel

a) SOx

Figure 6.44 is a forecast of SOx emission by fuel. The result shows petroleum products to be attributable for almost all (97% - 98%) SOx emission throughout the forecast period. This means the change in total SOx emission is identical to the change in SOx emission from petroleum products. The increase SOx emission from petroleum products from the base year 1990 (=1.0) to the years 2001, 2011 and 2021 are 2.0, 2.9 and 3.4, respectively (This trend is identical to the trend of total SOx emission). SOx emission from natural gas will grow by 5.1 times from 1990 to 2021. However, its impact to total SOx emission is negligible because the share of natural gas in SOx emission will not exceed 0.1 % throughout the period.

b) NOx

Figure 6.45 is a forecast of NOx emission by fuel. The result shows that about 90% the total NOx emission will be generated by petroleum products during the forecast period. The remaining 10% is generated by natural gas. The increase in NOx emission from the petroleum products and the natural gas from the base year 1990 (=1.0) to the years 2001, 2011 and 2021 are 2.3 and 4.1, 5.3 and 2.8, 4.2 and 6.3 respectively.

c) CO_2

Figure 6.46 is a forecast of CO_2 emission by fuel. CO_2 emission will be caused mainly by petroleum products and natural gas during the forecast period. The share of petroleum products in CO_2 emission will remain at 70% and the share of the natural gas will fluctuate between 20% and 25% during the period. The increase in CO_2 emission from petroleum products and natural gas from the base year 1990 (=1.0) to the years of 2001, 2011 and 2021 are 2.1 and 3.2, and 3.9 and 2.5, 3.6 and 5.1, respectively.

Fig. 6.39

I. R. IRAN / Estimation of Energy Balance Table by JICA Team

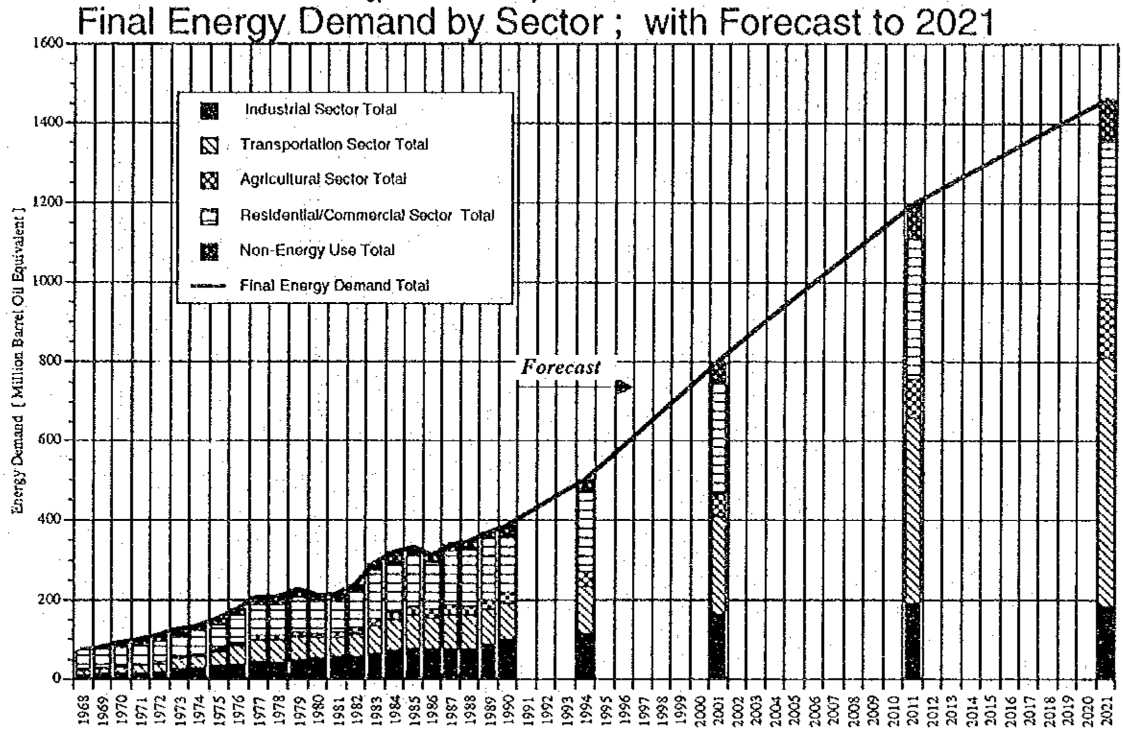


Fig. 6.40

I. R. IRAN / Estimation of Energy Balance Table by JICA Team

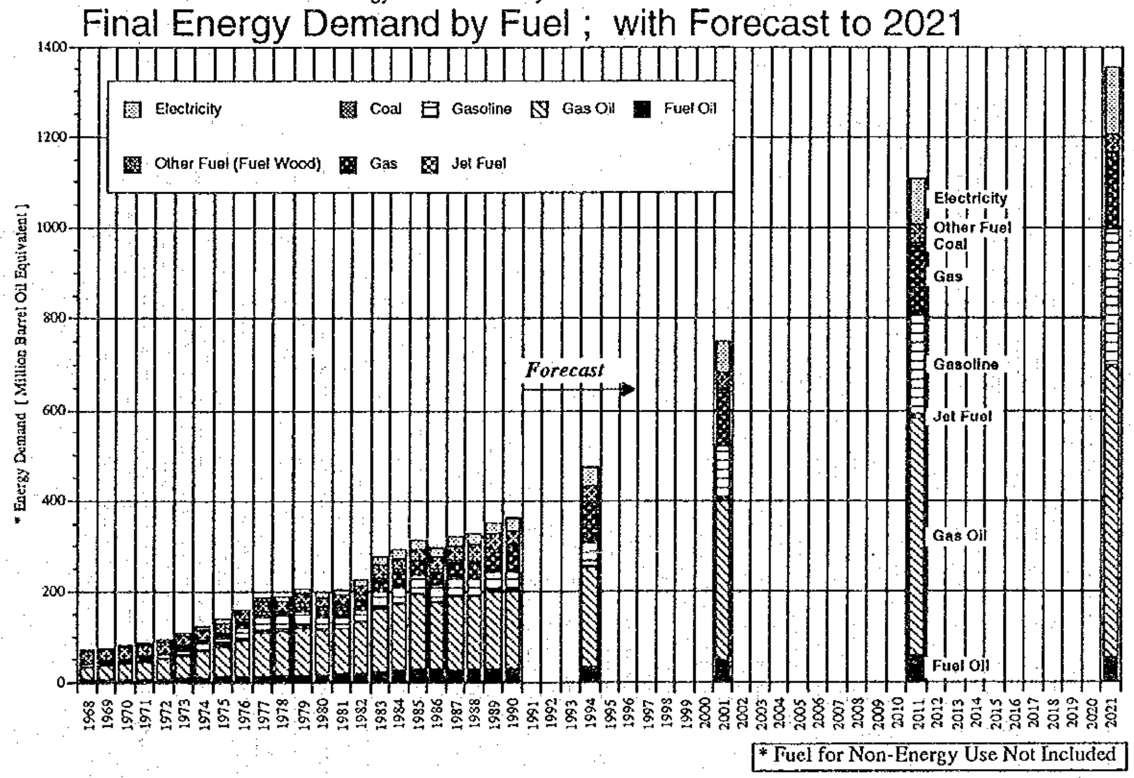


Fig. 6.41

SOx Emission by Sector with Forecast to 2021 ; I. R. IRAN

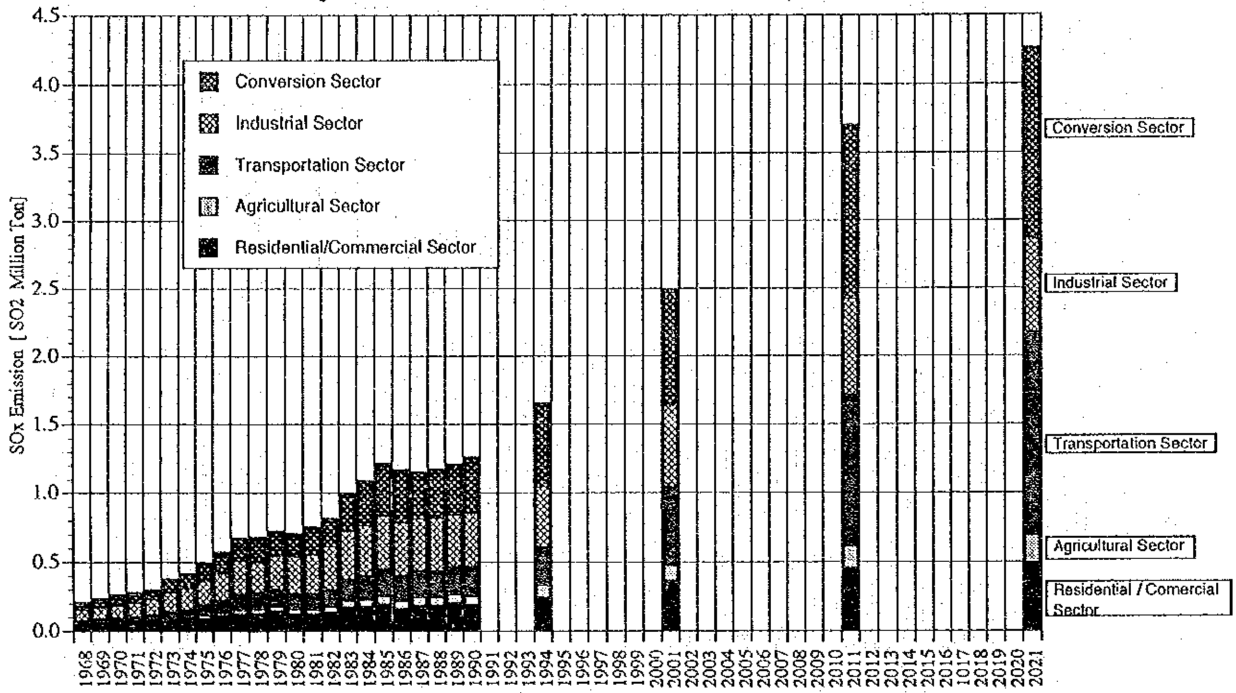


Fig. 6.42

NOx Emission by Sector with Forecast to 2021 ; I. R. IRAN

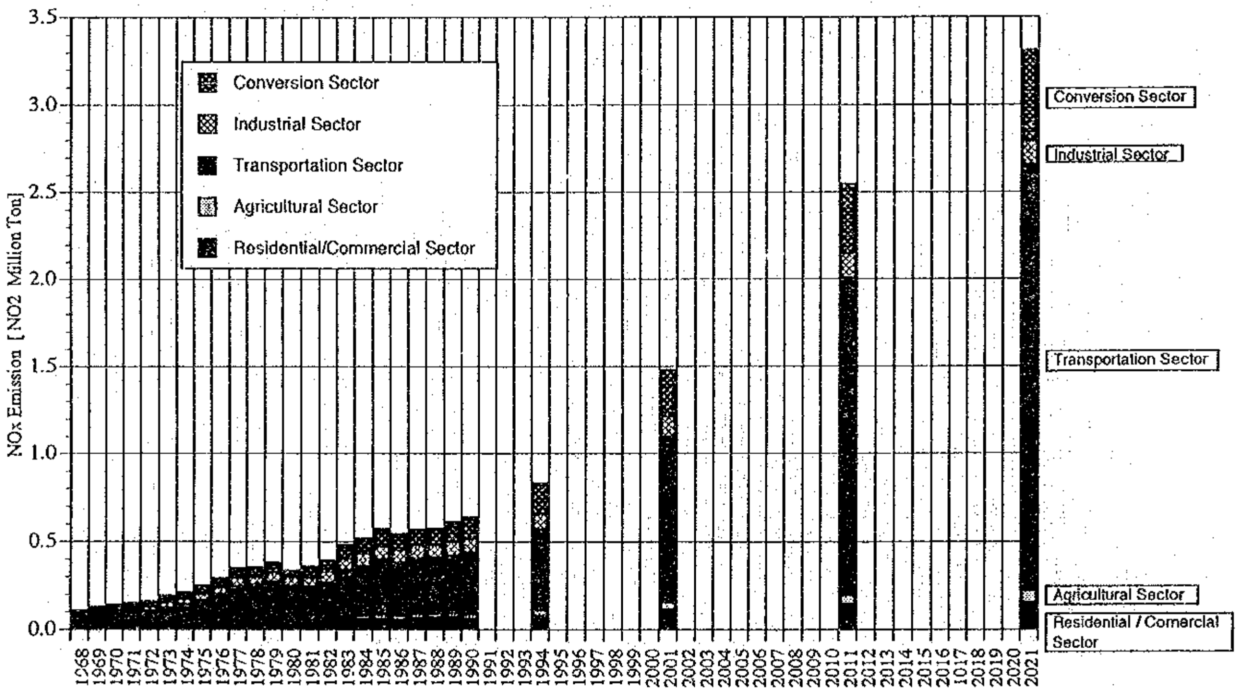
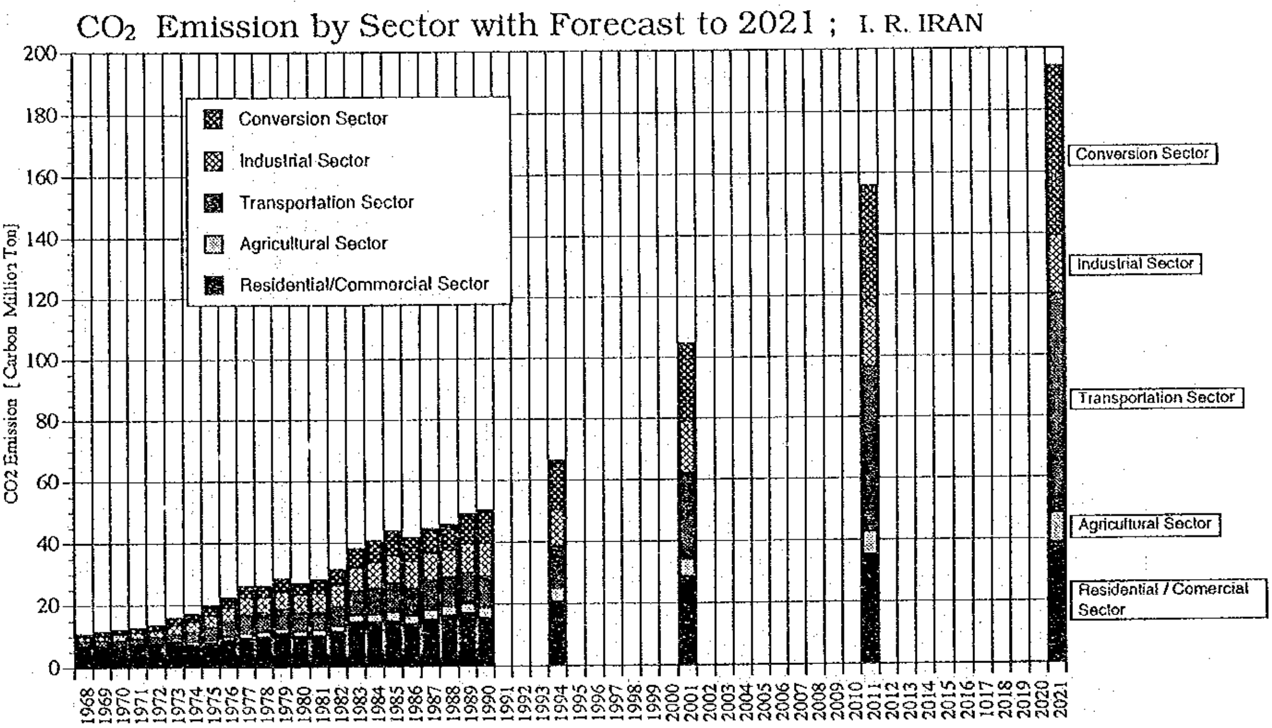
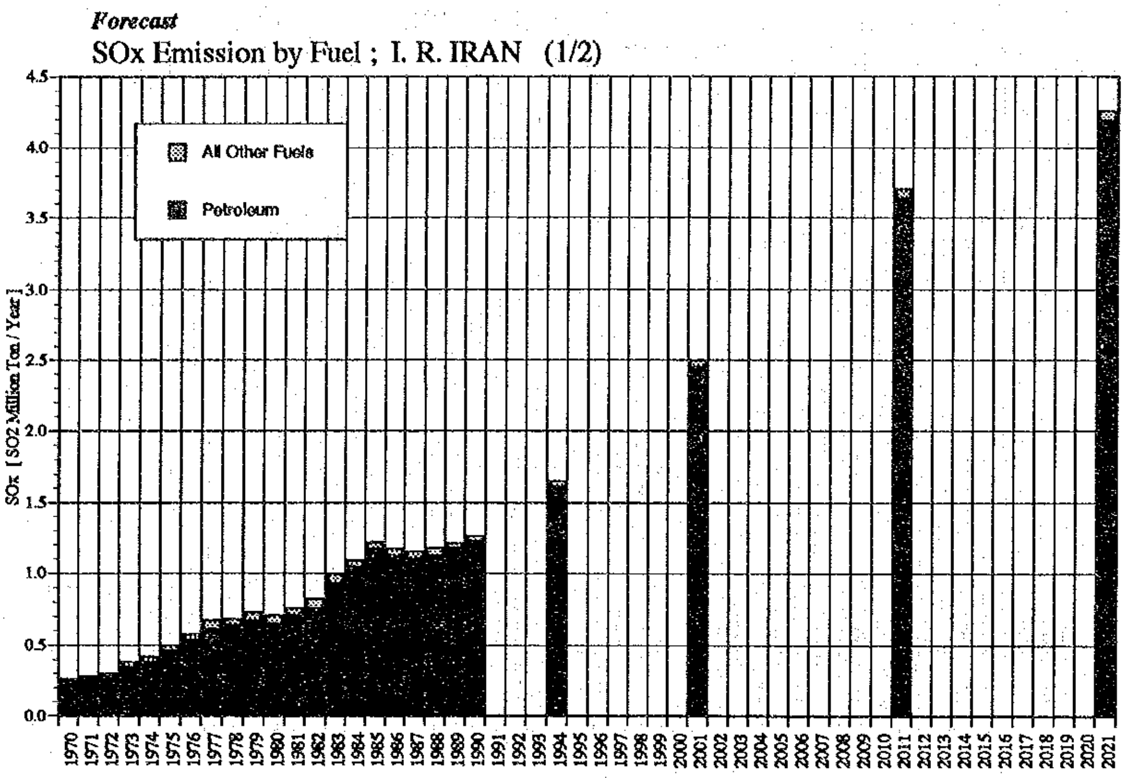


Fig. 6.43



CO_2 Emission by Sector with Forecast to 2021 ; I. R. IRAN
CO2 Emission [Carbon Million Ton]
200
180
160
140
120
100
80
60
40
20
0
Conversion Sector
Industrial Sector
Transportation Sector
Agricultural Sector
Residential/Commercial Sector
Conversion Sector
Industrial Sector
Transportation Sector
Agricultural Sector
Residential / Comercial Sector
1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 1017 2018 2019 2020 2021

Fig. 6.44


Forecast
SOx Emission by Fuel ; I. R. IRAN (1/2)
All Other Fuels
Petroleum
SOx [SO2 Million Ton / Year]
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5

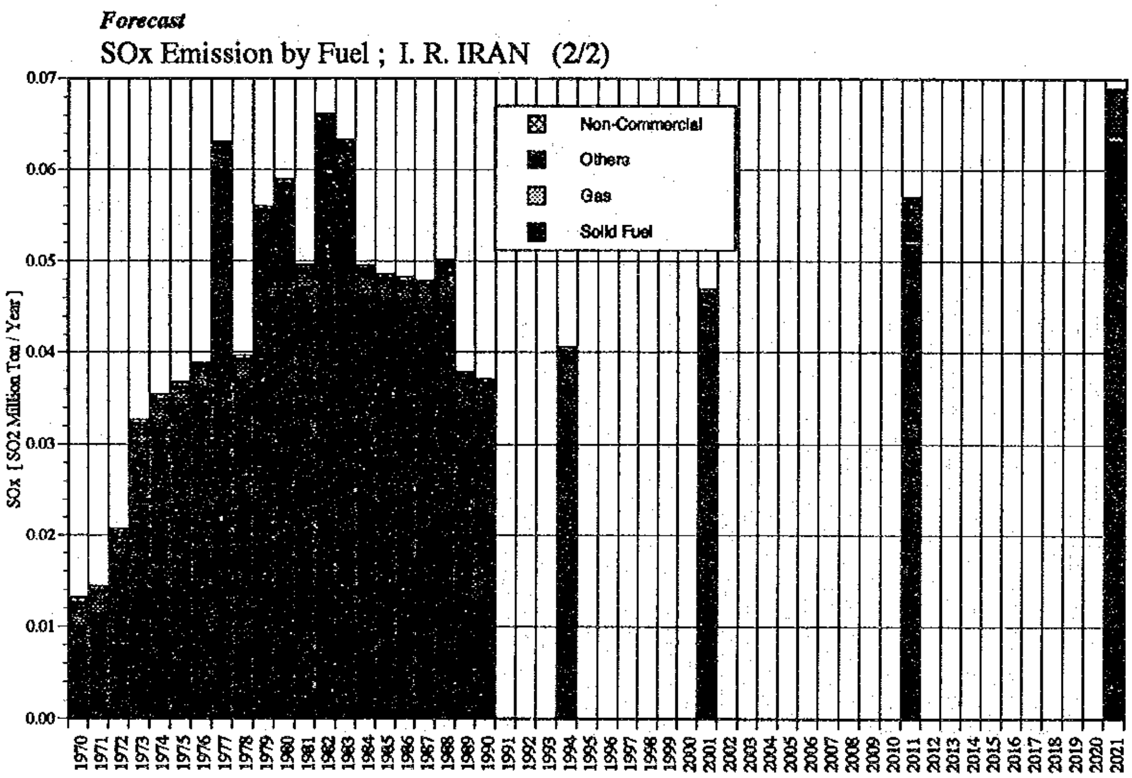
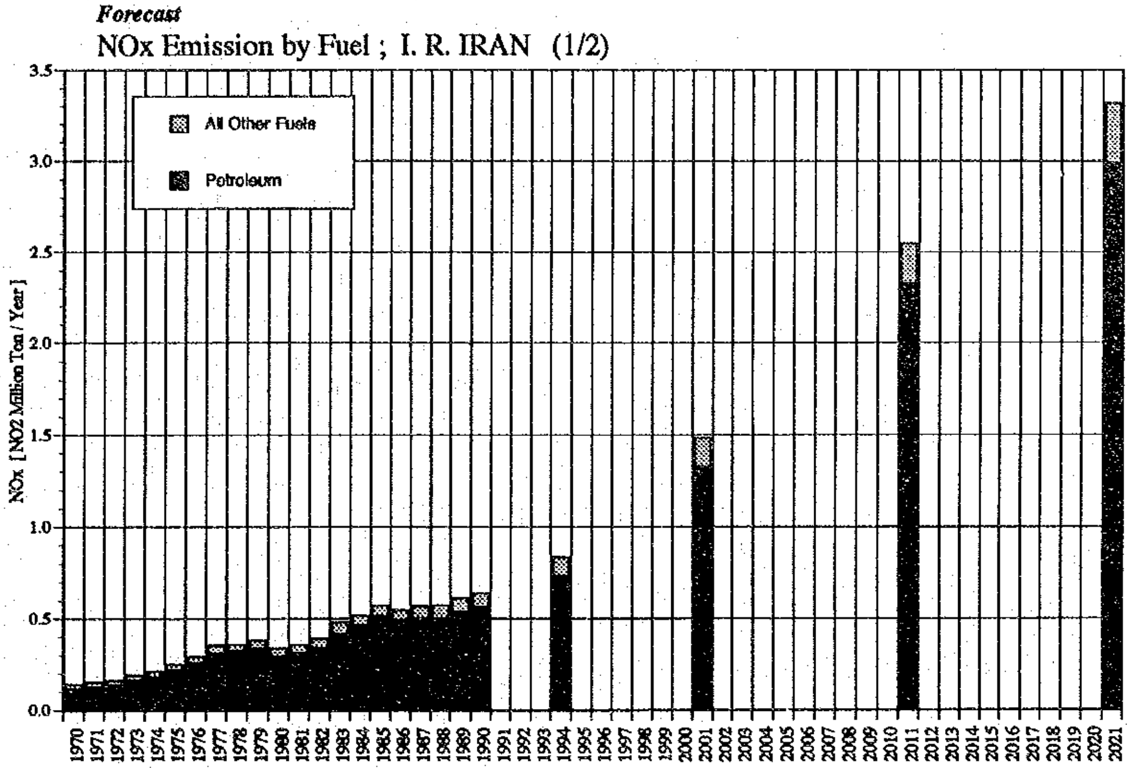
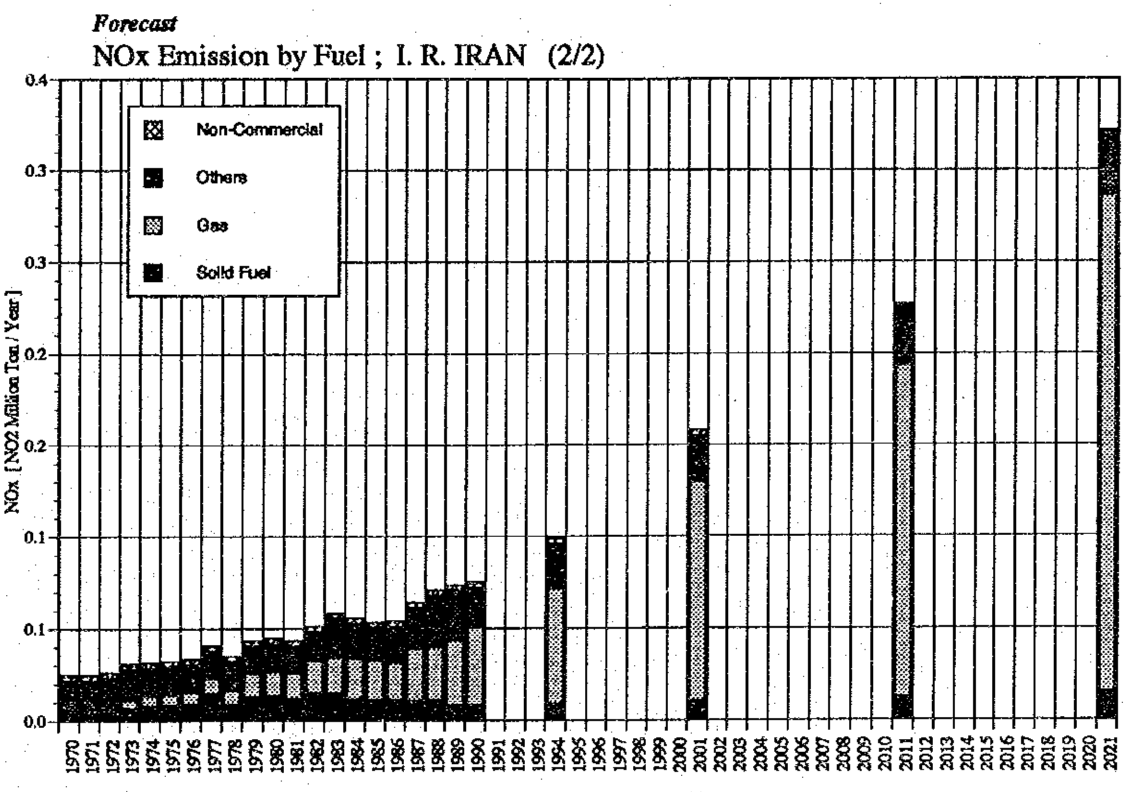

Forecast
SOx Emission by Fuel ; I. R. IRAN (2/2)
Non-Commercial
Others
Gas
Solid Fuel
SOx [SO2 Million Ton / Year]
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07

Fig. 6.45



Forecast
NOx Emission by Fuel ; I. R. IRAN (1/2)
All Other Fuels
Petroleum
NOx [NO2 Million Ton / Year]
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021

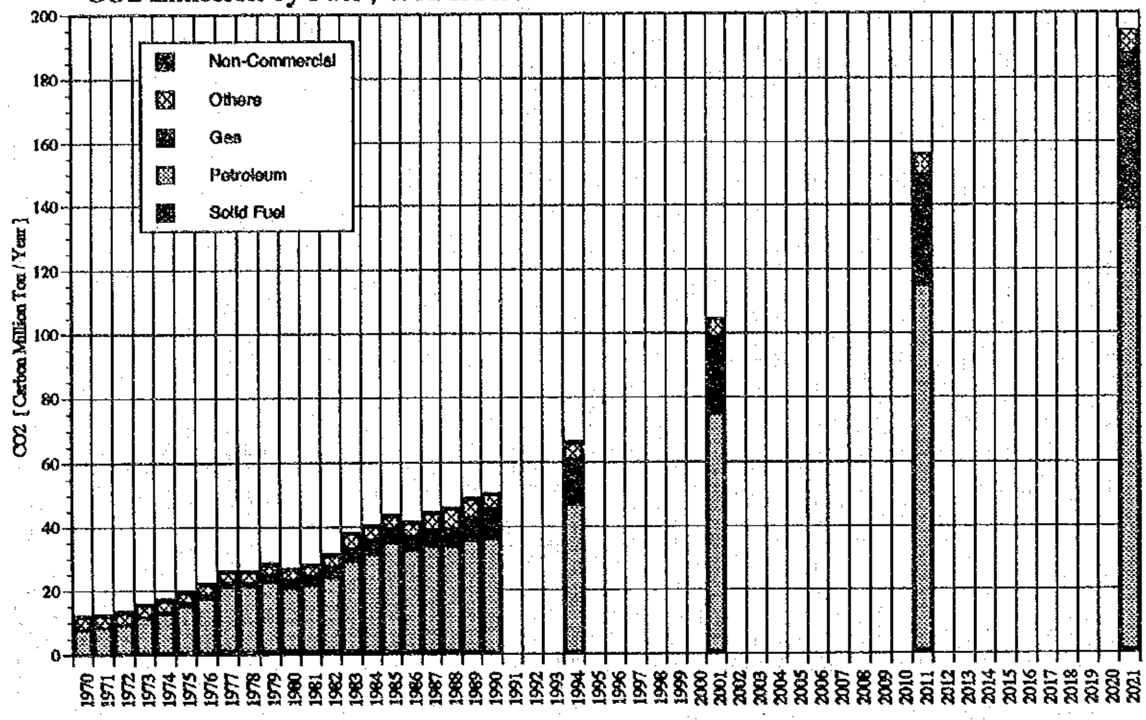


Forecast
NOx Emission by Fuel ; I. R. IRAN (2/2)
Non-Commercial
Others
Gas
Solid Fuel
NOx [NO2 Million Ton / Year]
0.4
0.3
0.3
0.2
0.2
0.1
0.1
0.0
1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021

Fig. 6.46

Forecast

CO2 Emission by Fuel ; I. R. IRAN

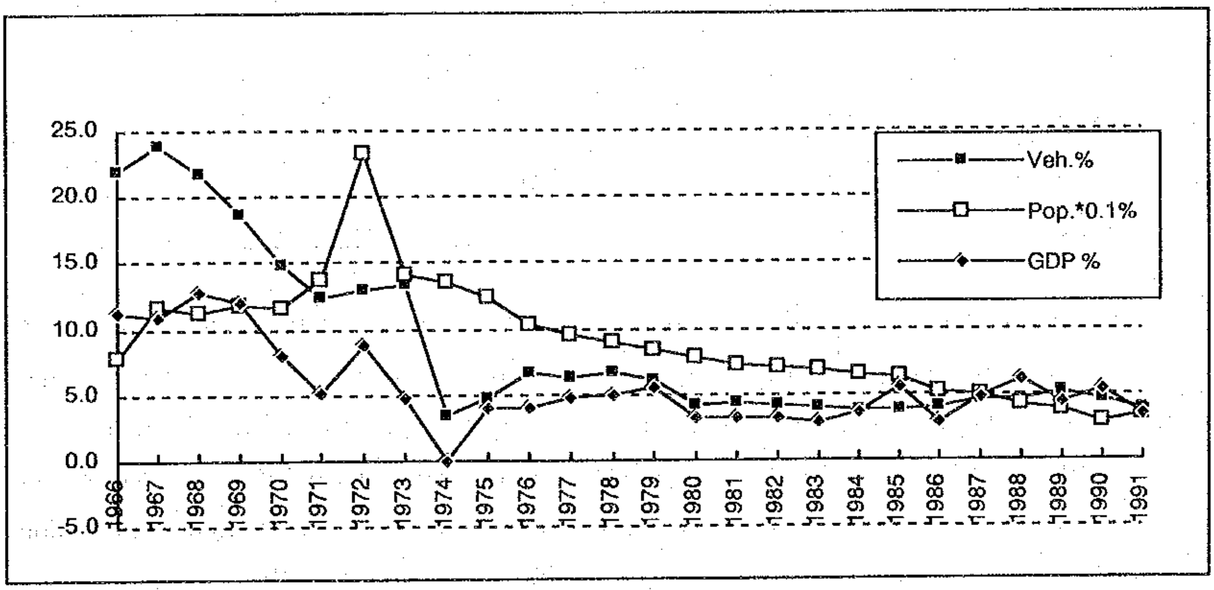


6.5.2 Forecast of Vehicle Stock and Emission Volume

(1) Whole Nation

Pollutants emission in the transportation sector will increase due to a growth in vehicle stock. The vehicle stock is estimated based on the assumption that annual vehicle stock growth will follow annual the trend of GDP growth trend, since an observation on the fluctuation patterns of growth rates of these two parameters show a resemblance with each other. This trend can be seen both in I.R. Iran and Japan, as shown in Figures 6.47 and 6.48 below.

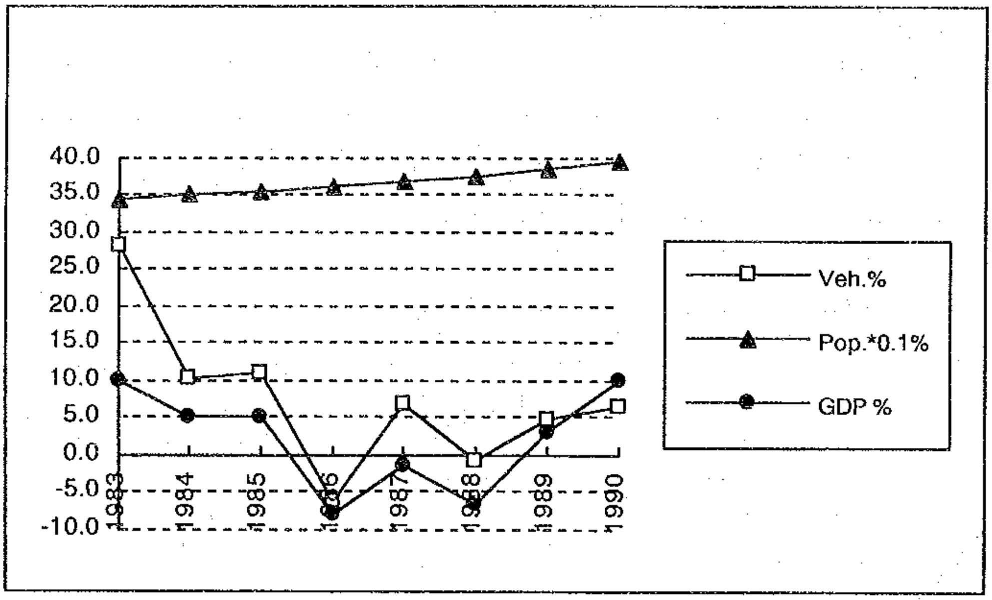
Fig. 6.47 Growth of Population, GDP and Vehicles in Japan



By this estimation, the vehicle stock in the year 2021 will be about 37 million(See Table 6.17).

The vehicle stock in I.R. Iran has shown rapid growth during the last 22 years, growing at an average rate of about 10% per annum. It may, however, be difficult to maintain such a growth rate since the major cities like Tehran have almost reached a point where urban road traffic is saturated, and has little room left for being able to accept more vehicles. The annual increment of vehicle stock will be estimated to be big at first, but smaller as time elapses. Also, the estimation was the assumption that no particular restrictions concerning vehicle numbers will be imposed or ruled out, and it would therefore be necessary to review it when any policy condoning the transport sector not will likely affect the vehicle stock is proposed.

Fig. 6.48 Growth of Population, GDP and Vehicles in I.R. Iran



Though vehicle stock is estimated to increase steadily, a part of the stock must be scrapped every year for reasons including aging of the vehicles in particular. This means that the annual increments of the vehicle stock consist of the newly registered vehicles minus the number of scrapped vehicles in each year. The number of scrapped vehicles can not be known because no control on vehicle scrapping has yet been enforced in I.R. Iran. The most likely reason for scrapping could be a retirement of the aged vehicles for a very long life of the Iranian vehicles.

As for the age of vehicles in Tehran, it is said that 44% of the gasoline fueled passenger cars are less than 15 years old and the,remaining 56% over 15 years, and 48% of the diesel fueled buses are less than 10 years old. Assuming that the age composition of the vehicle stock in 1990 is evenly distributed, and the number of scrapped vehicles is determined by assuming they are scrapped only after the expiration of their lifespans, it can be said that the lifespan of gasoline-fueled vehicles is 34 years and diesel -fueled vehicles 21 years.

Emission factors of each pollutant in I.R. Iran are assumed as follows;

a) SO_2 emission factor ($E(SO_2)$)

Iranian gas oil is reported to contain 0.8 - 1.0 % sulfur in weight, and this corresponds to an emission of 16 to 20 kg of SO_2 equivalent. One Kl of gas oil generates 8.742 Gcal of heat. Average annual energy consumption of one gas oil car is estimated at about 38.00 Gcal,so that one gas oil vehicle emits 68 kg of SO_2 per year as calculated below:

E(SO2)= 75.63(kg/y*Veh.)=18 (kg/t) *0.870(t/Kl) * 38.00 (Gcal/y)/ 8.742 (Gcal/Kl)

b) NOx emission factor (E(NOx))

NOx is emitted by both gasoline and gas oil cars. The emission factor of 3.17 kg/Gcal for gasoline cars, and 2.74 kg/Gcal for gas oil cars are assumed referring to information in the report issued by the Science and Technology Agency, Government of Japan in 1992 entitled "Energy Use and Global Environment". Average annual energy consumption of one gasoline and one gas oil car are estimated at 13.82 Gcal and 38.00 Gcal, respectively, so that one gasoline vehicle emits 44 kg NOx per year, and one gas oil vehicle emits 104 kg, as calculated below:

<Gasoline car>
E(NOx)= 43.81(kg/y*Veh.)=3.17 (kg/Gcal) * 13.82 (Gcal/y)

< Gas oil car>
E(NOx)= 104.12(kg/y*Veh.)=2.74 (kg/Gcal) * 38.00 (Gcal/y)

c) CO_2 emission factor ($E(CO_2)$)

CO_2 is emitted by both gasoline and gas oil cars. The emission factor of 3,132 kg per ton of fuel for gasoline cars, and 3,187 kg per ton of fuel for gas oil cars are assumed referring to information in the report issued by the Science and Technology Agency, Government of Japan in 1992 entitled "Energy Use and Global Environment". Average annual energy consumption of one gasoline car and one gas oil car are estimated at 13.82 Gcal and 38.00 Gcal, respectively, so that one gasoline vehicle emits 4,328 kg CO_2 per year and gas oil vehicle emits 12,052 kg, as calculated below:

< Gasoline car>

$E(CO_2)$= 4,328 (kg/y*Veh.)=3,132 (kg/t) * 0.780(t/Kl) * 13.82 (Gcal/y)/7.801(Gcal/Kl)

< Gas oil car>

$E(CO_2)$=12,052 (kg/y*Veh.)= 3,187 (kg/t) * 0.870(t/Kl) * 38.00 (Gcal/y)/8.742(Gcal/Kl)

c) HC emission factor (E(HC))

The emission factor of HC is drawn from "OECD Environmental Data 1991" as shown in Table 6.16. These indices of different countries show descending trends of HC emission since 1970 as the measures for emission control was introduced in most of these countries. Since full-scale emission control on the vehicle exhaust gases has not yet been enacted in I.R. Iran, an average of the figures in 1970 of selected western countries--the HC emission factor of 4.5 kg /Gcal--is taken to represent the present situation.

Table 6.16 HC Emission by Mobile Source

Country	Emission Factor (kg/Gcal)			
	1970	1980	1985	1989
Canada	5.5	2.9	3.1	2.4
USA	4.0	2.1	1.8	1.5
W.Germany	4.4	3.6	3.4	2.9
Italy	2.9	2.7	2.6	2.4
Netherland	6.7	3.4	2.9	2.6
Sweden	7.7	4.4	4.4	3.9
Switzerland	2.9	2.6	2.3	1.5
UK	2.0	2.3	2.2	2.2
Average	4.5	3.0	2.8	2.4

Source: OECD Environmental Data 1991

The annual HC emission factors by vehicle fuel type is estimated as follows:

<Gasoline>

E(HC)= 62.19 (kg/y*Vehicle)(=4.5 (kg/Gcal) * 13.82 (Gcal/y))

<Gas oil>

E(HC)= 171.00 (kg/y*Vehicle)(=4.5 (kg/Gcal) * 38.00 (Gcal/y))

The amount of pollutant emission is estimated to increase at two to four times as much as the present speed if no measures for pollutant reduction are taken until the year 2021, as shown in the Tables 6.17 below.

Table 6.17 Projection of Vehicle Stock by Type and Emission

Year	Vehicle Stock			Pollutant(1,000t /y)			
	Total	Gasoline Car	Gas Oil Car	SOx Total	NOx Total	CO2 Total	HC Total
1991	6,176	4,448	1,728	131	375	40,078	572
1996	11,302	8,140	3,162	239	686	73,341	1,047
2001	16,297	11,737	4,560	345	989	105,756	1,510
2006	19,887	14,322	5,564	421	1,207	129,049	1,842
2011	22,365	16,107	6,258	473	1,357	145,132	2,072
2016	25,838	18,608	7,229	547	1,568	167,664	2,393
2021	36,525	26,305	10,220	773	2,216	237,015	3,383

(2) Tehran

Pollutant emission in each province will generally tend to rise as pollutant emission of the whole nation increases, but might vary from region to region depending on its economic development level. The forecasts show a remarkable growth in I.R. Iran in terms of population and domestic production. Generally speaking, economic growth will progress more rapidly in relatively less developed than in already urbanized regions. This also applies to the vehicle stock growth rate, which means that the relative weight of the more advanced regions like Tehran will tend to descend in spite of national development. For example, the following Japanese statistics clearly indicate a relative recession in Tokyo in its share of the population and total vehicle stock.

Table 6.18 Change of Status of Tokyo, Japan

Year	Share of Total Pop.(%)	Share of DID Pop.(%)	Share of Veh. (%)
1,960	10	22	19
1,965	11	21	15
1,970	11	19	12
1,975	10	18	9
1,980	10	16	8
1,985	10	16	8
1,990	10	15	7

Though the population of Tokyo relative to the total population has almost been constant for 30 years, the share of DID population has fallen to 70 %, and the share of the vehicle stock to less than half of 30 years ago. Here, it is assumed that Tehran City will follow a trend that is similar to Tokyo in the future to the growth of national economic activities.

Table 6. 19 Assumption on Status of Tehran

	1990	2010
Share of DID Pop.(%)	36	33
Share of Gasoline Car Stock(%	40	30
Share of Gas oil Car Stock(%)	15	18

The amount of pollutant emission is estimated to increase five to six times the present level if no control measures are taken until the year 2021, as shown in the Table6.20 below.

Table 6.20 Projection of Vehicle Stock by Type and Emission in Tehran City

Year	Vehicle Stock			Pollutant(1,000t /y)			
	Total	Gasoline Car	Gas Oil Car	SOx Total	NOx Total	CO2 Total	HC Total
1991	1,879	1,603	276	21	99	10,265	147
1996	3,367	2,858	509	39	178	18,509	265
2001	4,743	4,001	742	56	253	26,259	376
2006	5,650	4,735	915	69	303	31,517	451
2011	6,199	5,160	1,039	79	334	34,854	499
2016	6,982	5,770	1,212	92	379	39,583	566
2021	8,962	7,170	1,792	136	501	52,628	752

6.6 Countermeasures and Capital Requirements

6.6.1 Countermeasures for Stationary Sources

In 6.3.2.1, the pollution sources and their countermeasures are outlined for 9 industrial sub-sectors. The capital cost requirements for environmental abatement, which compares to each facility's total investment in these industrial sub-sectors, is shown in Table 6.21. The result of evaluation is displayed by classifying the magnitude of the costs as 'Large', 'Small' or 'Negligible'.

6.6.1.1 Supply of Clean Fuels and Fuel conversion

To supply low sulfur fuel oil (kerosene, gas oil and fuel oil) to various fuel oil users is the most simple and reliable countermeasure for SOx pollution prevention. And in this respect, it is expected to become common in I.R. Iran in the near future to supply clean fuels especially to small-and medium-scale industries, or to supply natural gas as is a general trend among the developed countries. However, a large amount of capital investment is necessary to produce low sulfur fuel oils, especially low sulfur heavy fuel oil. Figure 6.49 shows the indicative construction costs of petroleum refining plants by various processes.

Fig. 6.49 Petroleum Refining Plant Cost

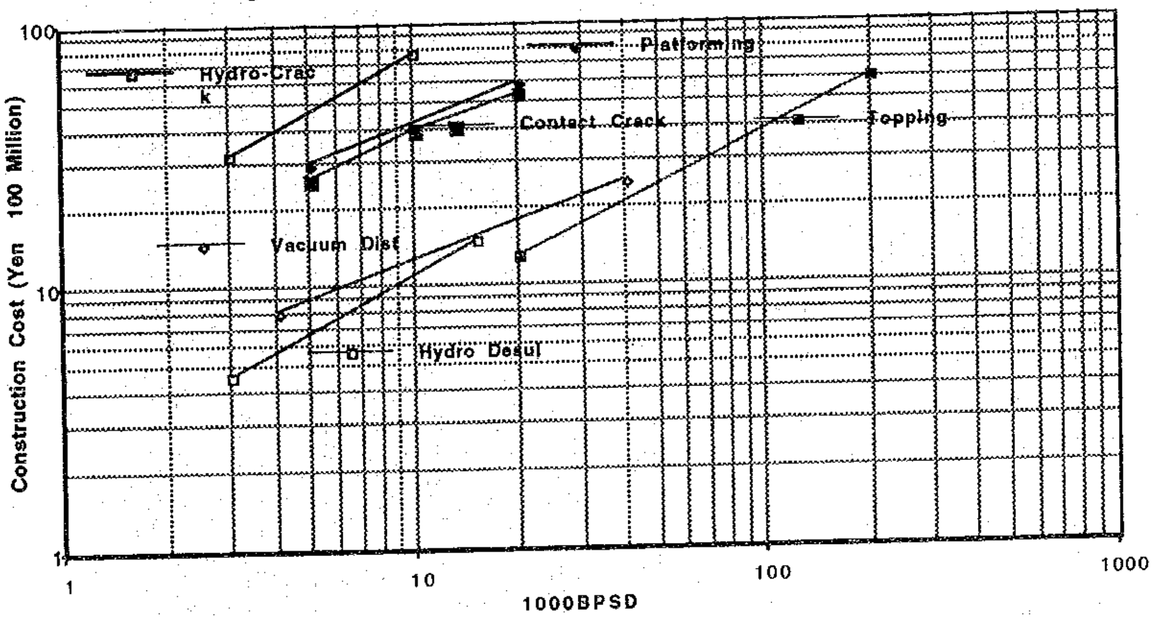


Table 6.21 Pollution Abatement Cost Impact on Production Investment

	Pollutant	Process Source	Countermeasure	Industries								
				Steel	Power	PetRef	PetChem	Gas	Paper	Cement	Sugar	Glass
Air	SOx	Process	Reduce sulfur content in feed	-	-	-	-	LorM&P	-	-	-	-
		Boiler, Furnace, Reactor	Fuel conversion to gas	N	S	-	S	-	S	S	S	S
			Reduce sulfur content in fuel	N	S	LorM&P	N	-	N	N	N	N
			Flue gas de-sulfurization	M	M	S	M	-	M	-	L	M
			Integrated high stack	S	S	S	S	-	M	M or S	M	M
			Sulfur recovery	S & P	-	M & P	-	MorS&P	-	-	-	-
	NOx	Process, Heater	Fuel conversion (Coal→Heavy oil→Natural gas	S	S	M & P	S	-	S	S	S	S
		Boiler, Furnace, Gas turbine	Low-NOx burner	N	S	N	N	N	S	N	S	S
			Modified burning	N	N	N	S	-	N	N	M	S
			Flue gas de-nitrification	M	M	S	M	-	M	M	L	M
	Dust	Various places	Closed space dust collecting	M & P	S or M	-	S & P	-	M	M & P	-	S & P
	Smoke	Flare stack	Smokeless burning	N	-	N	N	N	-	-	-	-
			Waste gas recovery	S & P	-	S & P	S & P	-	-	-	-	-
Water	BOD/COD	Process	Biochemical treatment, Coagulation precipitatio	N	N	S	M	N	M	-	M	-
	SS, Color	Process	Coagulation precipitation, Filtration	N	-	-	S	-	M	S	S	-
	Oil	Process, Ballast, Seal	Oil separater	-	-	S & P	S	N	-	-	-	-
	Heat	Condenser, Cooler	Cooling tower	S & P	S & P	S & P	S & P	-	-	-	-	S & P
	Settlement	Well	Decrease well water use	-	-	-	-	-	-	-	-	-
Waste	Dust	After collection	Recycle to applicable feed	S & P	-	-	-	-	-	S & P	-	S & P
	Slag	Furnace	Re-utilization(for Cement, Civil materials)	S & P	-	-	-	-	-	S & P	-	-
	Oil	Oil separater	Dewatering and incineration	-	-	S	S	-	-	-	-	-
			Recycle to feed, or fuel	-	-	S & P	S & P	-	-	-	-	-
	Sludge	Water treater	Dewatering and incineration	-	-	S	S	-	S	-	S	-
			Dewatering and utilization as cement feed, etc.	S & P	-	M & P	-	-	-	S & P	-	-
Noise		Various places	Curtailing at sources, Shelter, Enclosure	N	N	N	N	N	N	N	-	-
Others			Plantation on premises, Telemetering system	S	S	S	S	S	S	S	N	N

Note ; "L", "M", "S" and "N" indicates magnitude of cost impact on total investment of an ordinary production unit of the industry.
(L = Large : 10 ~ %, M = Medium : 5 ~ 10 %, S = Small : 1 ~ 5 %, N = Negligible : Less than 1 %)
"-" denotes "not applicable".
"P" means "productive", by saving or producing products or by-products.

In I.R. Iran, it is forecast that there will be a shortage of lighter fuel oil will in the near future if conversions are not made from the heavier fuel oil or atmospheric distillation residuals. Although most of the Iranian crude oil cannot easily be converted due to its higher metal content, it will be much needed to process the surplus heavier stocks to produce lighter low sulfur fuel oils to fulfill future demand even if it means using indirect and complicated desulfurization processes.

6.6.1.2 Countermeasures for Flue Gas

(1) Flue Gas Desulfurization

A wide variety of FGD methods is being used, although many of them resemble to each other in principle. The methods are classified into wet, semi-dry and dry type depending on the use of water in their absorption process of FGD plants.

- Wet Type FGD Methods

a) Limestone - Gypsum Method
   * Spray Tower Method
   * Jet Bubbling Method

b) Others

- Semi-dry Type Methods

a) Spray Dryer Method

b) Others

- Dry Type Methods

a) Activated Carbon Method

b) Coal Ash using Method as Absorbent

c) Simplified FGD Method (Dry Absorbent Injection into Furnace)

d) Simple FGD Method (Dry Absorbent Injection into Duct)

e) Others

Judging from the current trends of FGD technologies in the world, the limestone-gypsum method, in which limestone slurry is used as the absorbent, is the most popular among the wet methods being employed by many utility plants. In Japan, the number and total capacity of FGD was increased from 102 units and 5.4 million Nm^3/h (1970), to 994 units and 79.4 million Nm^3/h (1975), to 1,741 units and 154.5 million Nm^3/h (1980), and to 1,180 units and 176.3 million Nm^3/h (1988). The rapid increase in total treatment capacity of FGD facilities contributed to the reduction of SOx emission from stationary emission sources, particularly in industrial and energy conversion sectors including many power plants. The results taken by 15 continuous monitoring stations show that SO_2 concentration in the air improved remarkably from 0.043 ppm in 1970 to 0.021 ppm in 1975 and to 0.010 ppm in 1986.

Figure 6.50 shows the investment cost of FGD plants. According to the Industrial Pollution Control Association of Japan (IPCAJ), sodium and magnesium scrubbing plants which recover the waste liquor can be built and operated at considerably low cost, that is about 150 million yen for gas producing capacity of 100 thousand Nm^3 (equivalent to 33 MW).

The construction cost of the plant which uses limestone as the absorber and recovers gypsum is about 20 thousand yen per kW. Sulfur and sulfuric acid recovering FGD plants cost more than 25 thousand yen per kW. Regarding the operation cost of limestone-gypsum method, the main part of the cost is electricity charges. Power consumption by a FGD plant adopting the limestone-gypsum system installed for a power generation boiler is about 1.5 - 2.0 % of the total generating power. The operation cost of a FGD plant (limestone-gypsum method) for a coal-fired boiler (plant cost : 20 thousand yen / kW) is estimated to be about 1.5 yen per kWh including 7 years' depreciation and 10 % interest.

Fig. 6.50 FGD plant cost

A : Sodium & magnesium
scrubbing waste liquor

B : Other processes

Source : IPCAJ

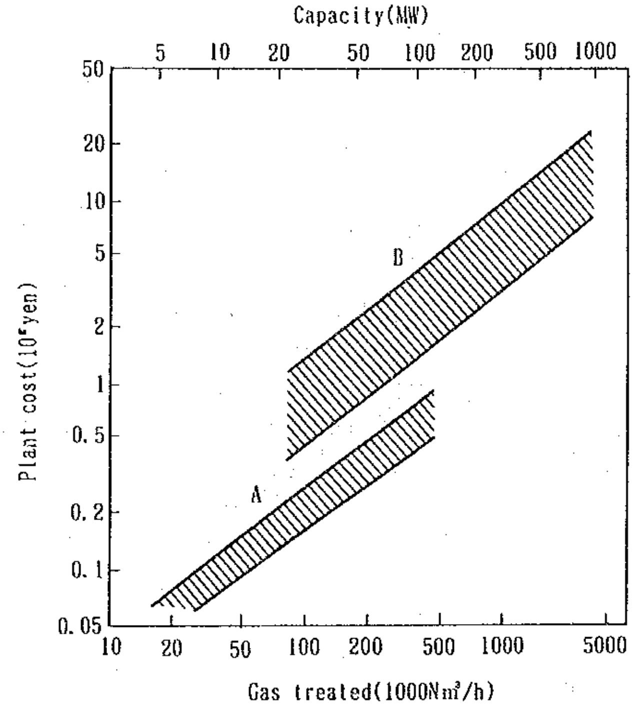


Table 6.22 Example of Capital Investment for FGD (Coal)

Technologies	Reduction Efficiency	\$ / kW	\$ / SO_2 (ton)	\$ / TOE
Wet FGD	over 90 %	150 - 280	350 - 600	23.4 - 40.1
Spray Drier	around 90 %	140 - 210	360 - 540	24.1 - 36.1
Dry Injection	around 50 %	70 - 120	420 - 750	15.6 - 27.9

Source ; Y.Kaya et., "Assessment of Technology Options for Mitigating Global Warming", 1991

Table 6.22 shows an example of investment costs for desulfurization in the U.S. In addition to the above technologies, new technologies such as Integrated Gasification Combined Cycle (IGCC) have been developed. These new technologies will bring about substantial improvements in both cost and efficiency.

(2) Flue Gas Denitrification

A major proportion of NOx originates from the combustion of fossil fuels. The generation of

NOx can be reduced to around half by combustion modification, as shown in Table 6.23.

Table 6.23 NOx Concentration in Combustion Gas

(Unit : ppm)

	Gas (N=o %)	Oil (N=0.1-0.5 %)	Coal (N=1-3 %)
Without CM	200 - 300	300 - 500	500 - 1,000
With CM	50 - 100	80 - 200	200 - 400

Note ; CM = Combustion Modification

Source ; Industrial Pollution Control Association of Japan, "Industrial Pollution Control, Vol. 1 Air and Water" ,1989.

The following technologies can be described as combustion modification for NOx abatement.

- Single System

a) Using Low NOx Burner (LNB)

b) Two Stage Combustion Method (TSC)

c) Fluidized Bed Combustion Method (FBC)

d) Flue Gas Recirculation Method (FGR)

e) Off-stoichiometric Combustion Method (OSC)

f) Others

- Combined System

a) LNB and TSC

b) LNB and FGR

c) TSC and FGR

d) LNB, TSC and FGR

Other than combustion modification technologies, plants using the Selective Catalytic Reduction (SCR) Method have been practically put into operation in Japan. The total number and total capacity of flue gas denitrification units in Japan increased rapidly from 45 units and 4.3 million Nm^3/h (1975), to 140 units and 63.6 million Nm^3/h (1980), to 305 units and 125.9 million Nm^3/h (1985), and to 379 units and 152 million Nm^3/h (1988). Increased capacity has contributed to the reduction of NOx emission from stationary sources including the power sector.

Table 6.24 shows the investment cost for combustion modifications including the replacement of burners and improvement of furnaces, and Figure 6.51 shows the relationship between the NOx reduction ratio and cost performance of each technology. According to IPCAJ's report, OSC can adjust some of the many burners to have excess air and the rest of them to have air deficiency, and then can reduce NOx up to about 20 % at the lowest cost. Both LNB and TSC methods can reduce NOx by about 30 -40%. Results of a sampling survey on the reduction ratio are shown in Table 6.25.

Table 6.24 Investment cost for Combustion Modification

Combustion Technologies	Cost (Yen/Nm^3/hr)
LNB	129
TSC	292
LNB + TSC	480
LNB + FGR	491
TSC + FGR	475
LNB + TSC + FGR	657
OSC	26

Source : Industrial Pollution Control Association of Japan, "Industrial Pollution Control, Vol. 1 Air and Water", 1989.

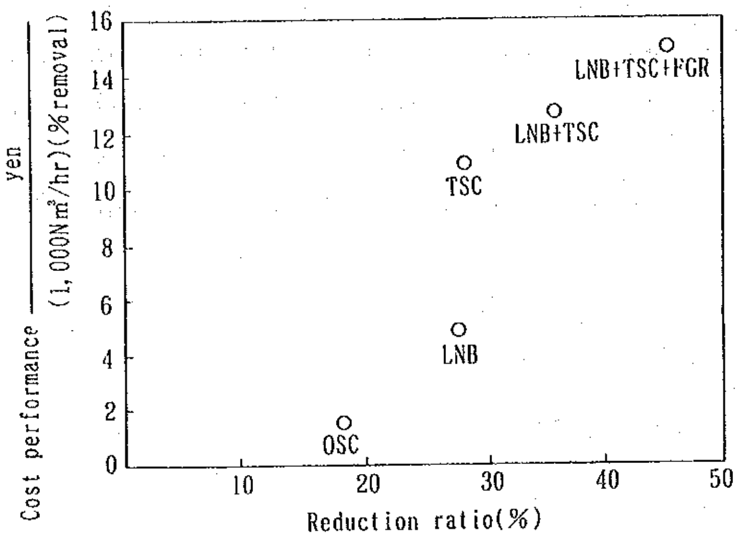
Table 6.25 NOx Control Results by Combustion Modification

NOx Abatement Methods	NO. of Samples	Before Installation (ppm)				After Installation (ppm)				Reduction Ratio (%)
		Mean.	Min.	Max.	SD	Mean.	Min.	Max.	SD	
Low Nox Burner (LNB)	97	167	35	1000	106	116	29	650	76	31
Two Stage Combustion (TSC)	41	73	61	222	40	46	37	133	27	37
Flue Gas Recirculation (FGR)	1	280	280	280	0	270	270	270	0	4
Others	44	434	39	2250	630	235	2	1125	356	46
LNB + TSC	23	305	35	700	187	181	28	490	115	41
LNB + FGR	6	125	62	247	74	80	27	176	59	36
TSC + FGR	5	143	115	176	24	116	76	141	31	19
LNB + TSC + FGR	24	182	47	450	108	111	43	290	53	39

Note: NOx concentration is adjusted for O_2 = 6%

Source: Tatsuo Hiratani, "Regulatory Environment and Ingredients of Industrial Pollution Control in Japan", Industrial Pollution Control Association of Japan,

Figure 6.51 Cost Comparison of NOx Control Techniques Applied to Boilers



Source : IPCAJ

Table 6.26 shows the plant cost of operating the SCR method on large-sized boilers of 250 - 700 MW and the operation cost. The plant cost includes initial cost of catalyst and civil engineering. The operating cost includes 7 years' depreciation. It is assumed that the catalyst life is 4-5 years for coal-fired boilers and 7 - 10 years for oil fired boilers.

Table 6.26 Cost of SCR for flue gas from utility boilers (250 - 700 MW, 80 % NOx Removal)

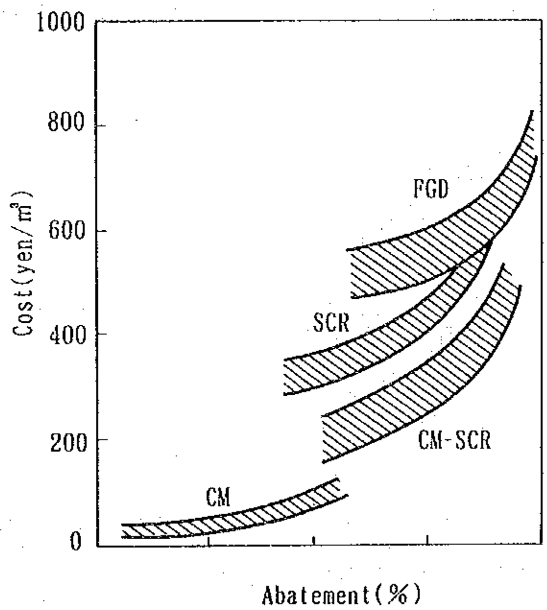
	Low-S Oil	High-S Oil	Coal
Plant cost (yen/kW)	3,500	5,000	6,000
Operation cost (yen/kWh)	0.20	0.30	0.40

Source ; Industrial Pollution Control Association of Japan, "Industrial Pollution Control, Vol. 1 Air and Water",1989.

(3) Comparison of SOx and NOx Abatement Costs

Figure 6.52 shows the estimated cost comparison of SOx and NOx removal technologies described previously. The cost estimation includes 7 years' depreciation and 10 % interest. Combustion modification is the most economical for NOx abatement. The SCR method should be used in combination with the CM method when CM is not sufficient to meet the standards. Though the FGD method appears generally more costly than other methods, it can remove two acid H+, and is considered more efficient than others in removing acid and preventing acid rain as well.

Figure 6.52 Cost Comparison of SOx and NOx Removal Technology



Source : IPCAJ "Industrial Pollution Control, Vol. 1 Air and Water", 1989.
Note : NOx without treatment ; 600 ppm for coal, 300 ppm for oil

6.6.2 Measures for Mobile Sources

Air pollution in I.R. Iran is mainly caused by the mobile sources in urban areas where intensive personal trips and freight transportation are generated due to integrated urban functions and its large population. For instance, it is reported that the air pollution in Tehran by statistics is related to the vehicles (65%), industrial units around the city (24%) and household heaters (10-15%) (Ref: Hamshahri, June 21,1993 and August 2, 1993, etc.) .

However, intercity traffics, mainly undertaken by motor vehicles, has a lighter environmental impact on I.R. Iran since most of the trunk roads are located in isolated areas. Therefore, the main target of combating air pollution against mobile sources will be urban areas, and particularly Tehran which is by far the largest city in the country.

This section is to propose an environmental consideration which should be reflected in the long term energy supply plan in the transportation sector including the energy end-users. Some control measures which are currently available or likely to be available in the near future in IR Iran have been chosen for studying the reduction of pollutant emission from mobile sources. From this point of view, the following four categories of control measures are investigated:

1) Improvement of traffic systems in urban areas
2) Improvement of vehicle performance
3) Supply of clean fuel
4) Introduction of clean-fueled vehicles

6.6.2.1 Improvement of Traffic Systems in Urban Areas (See also 5.2.3)

The control measures in this respect are generally classified into two categories: reduction of traffic volume, and relocation and dispersion of traffic from congested areas

a) Reduction of traffic volume

This is commonly attempted in many cities in the world in various manners. Restriction policy on vehicle possession and vehicle use is a basic approach taken by means of large amounts of compulsory payments such as vehicle registration fee, vehicle import tariff, road tax, additional registration fee and gasoline tax, and also by other obligations such as the vehicle assignment system, half tank rule and areal license system. These measures have been adopted systematically in Singapore and have achieved good control of the number of vehicles,but this seems to be an exceptional case where the measures poved successful thanks to the city's particularly advantageous nature such as its homogeneous social structure and small size. For the successful execution of this policy, it is also necessary that an alternative traffic measure be constructed simultaneously in the course of strengthening restrictions on vehicle possession and use.

b) Relocation and dispersion of traffic from congested areas

In Tehran, it is widely recognized that the present state of air pollution has reached a serious level and some control measures must be put into practice. The Mayor of Tehran reports the city that has planned to erect two satellite towns around the city in the future; one will be for service activities and the other for industrial activities. The company in charge of reorganizing the polluting industries is required to erect these towns in a way that they will not cause any pollution in Tehran (Ref: Tehran Times,October 23,1993). This kind of program will contribute not only to the direct reduction of pollutants emitted from service and industrial facilities, but also help reduce pollutants from those vehicles coming to these new towns which would otherwise go into Tehran City. This indirect reduction of pollutants will be much more signficant for traffic related to freight transportation because the major pollution sources of this kind of traffic will be relocated from inside Tehran to outside. This measure aims at removing a certain part of the traffic volume from congested areas to other places without changing the total traffic volume by relocating the industrial complex and a by designating entrance restriction zones in downtown. It will definitely serve to reducing the density of pollutant emissions, but all in all, very little could be expected in terms of total energy consumption or pollutant emission. The traffic condition which requires the gigantic amount of personal trips in Tehran may not change drastically even it such an ambitious relocation plan is implemented by erecting two new towns.

On the other hand, a modal shift in transport measures is considered very effective in reducing traffic volume. This measure can be applied to both personal trips and freight transportation; modal shift in transportation means from private cars to public mass transit systems and to railway freight transport. This willhave a significant effect on the transportation sector, resulting in better energy efficiency in those alternative transportation measures. Therefore, a modal shift is discussed extensively below as one of the most effective means of improving the traffic system in Tehran.The discussion focuses on personal trips with energy saving and pollutant reduction.

(1) Modal Shift for Personal Trips

A mass transit system for personal trips in urban areas will bring the most reliable impact on pollutant reduction. For example, Tehran has been operating an electric bus route since September, 1992 and is now successfully as a public commuter facility. Phase-1 of the project now in execution utilizes 35 buses, made in Czech sslovakia, with a capacity of 160 passengers. One passenger car in Tehran is reported to accommodate about 2 occupants per trip on average, so that one electric bus can substitute 80 passenger cars. The total numbers of passenger cars that can be replaced by 35 electric buses is 2,800 cars, and the amount of fuel saved is estimated to be about 70 % of 2,800 cars, according to the statistics on energy consumptioni of passenger cars and public buses in Japan as shown below.

<Comparison of Unit Energy Consumption in Japan>

- Railway :101 (kcal per person 1 km)
- Public bus :169 (kcal per person 1 km)
- Passenger car :574 (kcal per person 1 km)

(Source: Ministry of Transport, Japan, "Outline of Energy Related to Transport 1993",)

Though the electric bus system has an apparent effect on energy saving and pollutant reduction, this project is still in its initial stage, and no concrete plans for Phase-2 and after have not been announced yet. The measures for pollutant reduction by means of electric buses should be taken into consideration in long-term energy planning.

But, a railway transit system can achieve better performance than electric buses in saving fuel, which is estimated at about 80%, and its unit capacity is much bigger. In Tehran, a new subway network is now under construction. The whole subway system is planned to consist of four main lines, among which the first and second lines are expected to open soon. According to a newspaper report, an outline of the first and second subway lines is as follows:

-Total length	: 90 km
-Total construction cost	: Rial 200 billion
-Operating hours	: 4:00 a.m. to midnight
-Planned number of passenger	: 120,000 / hour on average
-Construction period	: 12 years so far ('76 to 81, 86 to 93 to ?)
-Executing agency	: Tehran Subway Enterprise

Based on the planned number of passengers per hour, the daily passenger is estimated at 2.4 million. Information on the current transportation means for an average daily personal trip is reported by the relevant authority of Tehran City as follows:

- Private car : 8.5 (million trips / day)
- Private van : 0.5 (million trips / day)
- Taxi : 1.6 (million trips / day)

- Motor bike : 2.7 (million trips / day)
- Bus : 4.2 (million trips / day)
- Total : 17.5 (million trip / day)

Of the total daily personal trips of 17.5 million in Tehran, 10.6 million (about 60 %) is made by gasoline cars such as private cars, private vans and taxis. Estimated personal trips of 2.4 million/day converted from motor vehicles to the railway which corresponds to 14 % of the whole trip and shares 23 % of the trip by gasoline cars. Because the gasoline car stock in Tehran City is estimated at approximately 1.6 million, the planned number of passengers on the first and second railway lines per day is expected to exceed 0.4 million gasoline cars, as calculated below:

-Number of vehicles replaced by railway: 0.4 million (= 1.6 million * (2.4 / 10.6))

The subway system is driven by electric power, and the electricity is generated outside Tehran, so that it would not be emitting any pollutants that would affect Tehran City if passenger cars were replaced with the subway. Though the planned capacity of the two subway lines has not been announced yet, it can be expected that another 400,000 passenger cars would be replaced by two additional subway lines, assuming that the new additional lines have the same capacity.

There is no definite information about when each line is to open. The following inauguration years can be expected on the basis of: 1) it takes about 15 years for the completion of the third and fourth lines, 2) the next stage of construction will commence just after the completion of the first and second lines:

- First and Second line : 1995
- Third and Fourth line : 2010

(2) Modal Shift for Freight Traffic

An example of a comparison of energy efficiencies among transport ation means is given from Japanese statistics as follows:

- Railway : 114 (kcal per 1 ton 1 km)

- Business truck : 649 (kcal per 1 ton 1 km)
- Private truck : 2,068 (kcal per 1 ton 1 km)

(Source: Ministry of Transport, Japan, "Outline of Energy Related to Transport 1993")

This comparison shows that the energy efficiency of railway is about six times that of business trucks and 18 times that private trucks. Though a shift in transport ation means from motor vehicles to railway seems influential for pollutant reduction, mainly because of the remarkable advantage in energy efficiency of the railway system compared to motor vehicle transportation, a shift of the share to railway transport will not contribute much to improve the urban environment. This is because most of the freight transporttion in urban areas consist of short-distance and light-weight deliveries except those connected to the industrial zone, whereas railway transport is suitable for heavy freight and long distances.

In a way, a modal shift for freight transport is considered just an indirect effect on the urban environment, and it is difficult to estimate its impact quantitatively. It is better to take this type of modal shift into consideration when a concrete plan is announced by the authorities.

6.6.2.2 Improvement of Vehicle Performance (See also 5.2.3)

"Statistics show that the most active cars in Tehran were produced before 1980. The problem is that most numbers of these cars are "Paykan", made in I.R. Iran, which were technically a failure even when they were first its assemblied back in 1963. The main technical problem of "Paykan" is its fuel system, burning 17 liters of gasoline for even 100 km. Experts say that the average gasoline consumption per each car in Tehran is 15 liters per 100 km, totalling 6 million liters of gasoline consumption per day in the city. It is clear that such gasoline consumption, two times that of world standards, plays a major role in polluting the city. The Iranian-made car "Paykan" is still being manufactured without technical changes having been made in its fuel system. The traffic organization in Tehran is looking for a solution ...." (Ref: Hamshahri, April 20, 1993).

The fuel efficiency of the Iranian car seems inferior to that of industrialized countries. The figure of 15 liters per 100 km corresponds to 6.7 km running distance per one liter of gasoline consumption, which is approximately half the efiiciency of a Japanese car. Furthermore, old cars account for a large share of its vehicle stock in I.R. Iran, and with no complete exhaust gas regulations. This situation suggests a substantial potential left for vehicle performance improvements.

(1) Strengthening of Vehicle Maintenance

A periodical engine check and good maintenance is an effective way to improve fuel efficiency. This will lead to the reduction of pollutant emission, especially considering special situation in Iran where a large number of old cars are in operation. To achieve this measure, enforce periodical checks and maintenance must be enforced under the official requirements, and checking items and target levels of the maintenance must be set forth. The capabilities of checking and maintenance agents, their capacities and facilities, should at the same time be promoted in order to meet the demand. The expected effectiveness of this measure in pollutant reduction b is 25 % in CO and HC emissions and 10 % in NOx emission. Maintenance costs required to comply to the official criteria reaches almost 80 % of the annual fuel expense in Japan as is shown in the Table 6.27, which means that if I.R. Iran is to adopt a similar exhaust gas control measure as the western countries, in the future the same maintenance costs must be borne by vehicle owners.

Table 6.27 Maintenance and Fuel Cost Ratio in Japan

Year	Fuel Consm. (1000 kl)			Price Index	Fuel Cost(A) (Billion ¥)	Mainte. Cost(B) (Billion ¥)	Ratio (A/B)
	Gasoline	Diesel	LPG				
1979	35,265	16,324	2,936	0.8	3,817	3,154	0.83
1980	35,512	16,893	2,908	0.8	4,161	3,546	0.85
1981	35,241	17,345	2,890	0.9	4,354	3,612	0.83
1982	35,279	17,593	2,815	0.9	4,488	3,651	0.81
1983	35,060	18,408	2,857	0.9	4,591	3,811	0.83
1984	34,314	19,521	2,821	0.9	4,676	3,978	0.85
1985	34,300	20,409	2,872	0.9	4,816	4,258	0.88
1986	34,685	21,431	2,885	0.9	4,941	4,100	0.83
1987	40,110	24,987	2,984	0.9	5,713	4,144	0.73
1988	41,180	27,262	2,938	0.9	5,987	4,367	0.73
1989	42,589	29,115	2,864	1.0	6,369	4,773	0.75

Source: Japan Motor Industry Association

(2) Improvement of Engine

An improvement of vehicle engines is highly necessary in I.R. Iran. The way of improving each engine type relevant to pollution emission is described below:

a) Improvement measures for gasoline cars

- Engine modification (ignition timing control, throttle positioned dashpot): target control substances=HC, NOx
- Exhaust gas recirculation (EGR): NOx
- Secondary air: HC
- Oxidation catalyst: HC, CO
- Three-way catalyst: HC, CO, NOx

b) Improvement measure for diesel cars

- Engine modification (retard fuel injection timing, optimum control of fuel injection timing & rate, supercharger with inter-cooler): Smoke
- EGR: NOx

c) Improvement measures for motorcycles

- Adoption of 4-cycle engine: HC, CO, Smoke
- Smokeless lube oil: Smoke, CO

These measures are taken to independently in combination in accordance with the required levels of official criteria. The practical measures adapting to the reality will be selected according to the decisions made on exhaust gas regulations.

(3) Introduction of Type Inspection

In Japan, strict exhaust gas regulations are imposed especially on new cars, executed by the governmental organization which is in charge of vehicle inspections in the form of official examinations by the Ministry of Transport. A chassis dynamometer unit is adopted for exhaust gas inspection in order to determine if an applicant prototype vehicle satisfies the criteria. The chassis dynamometer unit consists of the following elements:

- CVS system
- Gas analyzer
- Dilution tunnel

The installation cost of the unit is approximately 180 million yen for a small gasoline car, 210 million yen for a diesel car and 370 million. At least two operators are necessary for regular inspection. Though the inspection itself does not have any direct effect on pollutant reduction, it will key an indispensable role in ensuring the sound execution of the exhaust gas regulation when the related legislations are in effect.

6.6.2.3 Supply of Clean Fuel

Iranian fuel for motor vehicles is liable to cause air pollution. Leaded gasoline is still very commonly; the national car "Paykan" cannot be operated without leaded gasoline. The sulfur content of gas oil is as weii as 0.9 % on average, and this high content is a major cause of SOx pollution especially in large vehicles.

(1) Supply of Lead-free Gasoline

"The amount of lead released in the air in Tehran is 3.5 tons per day, mostly produced by gasoline engines. The Municipality of Tehran has proposed a research and study plan to produce lead-free gasoline with high octane and low RVP contents, that car manufactures should start assembling and or changing the fuel system of cars (Ref: The report of Teheran Traffic Control Center affiliated to the Municipality of Tehran "Comprehensive Plan for Controlling the Air Pollution in Tehran", February 3, 1993). The "Air Quality Control Company" established by the Municipality of Tehran in June 1991 is conducting study on "Engines regulation and its effect on the air pollution. "The Environmental Protection Organization (EPO) announced its policy in July 1993 that all the vehicle manufacturers and import agents are requested to produce and sell vehicles for which lead-free gasoline are suitable. Based on this decision, the Ministry of Heavy Industry, which is in charge of the vehicle industry, is expected to control motor vehicles that satisfy international standards.

National Iranian Oil Company is considering the supply of lead-free gasoline within six years from its refinery in Arak and other facilities.

(2) Desulfurization of Gas Oil

Iranian gas oil has a higher sulfur content than the international level. If sulfur content can be reduced to half of the present level, SO_2 emission will be reduced to half. If the sulfur content can be reduced to 0.2 % or less, which is the criterion of the Japanese Industrial Standard, and the industrial complex is relocated outside Tehran, the requirement of environmental standards for SO_2 will be satisfied.

(3) Supply of Oxygenated Gasoline

Due to the high altitude--about 1,500 meters above sea level--of Tehran, vehicles in the city tend to cause incomplete combustion with the thin air. As a remedy to this disadvantage, oxygenated gasoline could be used by mixing an oxygenating agent in the gasoline to supply oxygen in the combustion process. MTBE (methyl tertiary butyl ether) and ETBE (ethyl tertiary butyl ether) are usually adopted as oxygenated agents. The expected effects of this mixture is a 15 % reduction in CO and 10 % reduction in HC.

6.6.2.4 Introduction of Clean-Fueled Vehicles

Three types of clean-fueled vehicles, either under development or in partual practical use, are discussed. These cars will be the next-generation vehicles that will satisfy the current global requirements for sustainable development, might also be appropriate in meeting the energy supply structure of I.R. Iran. The selected vehicles are:

1) Electric car
2) Hybrid car (with electric and conventional engine)
3) CNG car (with natural gas-fueled engine)

The effect of these vehicles on pollution reduction is summarized by comparing the emission factor of each type of vehicle in Table 6.28 below.

Table 6.28 Emission Factors of Each Type of Vehicle

Polutant	SOx (g/km)		NOx (g/km)		CO2 (g/km)		HC (g/km)	
Fuel now in use	Gasoline	Gas Oil	Gasoline	Gas Oil	Gasoline	Gas Oil	Gasoline	Gas Oil
Convenional Engin	0	4.86	3.13	7.44	309	861	4.44	12.21
CNG Car	0	0	0.23	0.55	226	630	0.33	0.90
Electric Car	0	0	0.02	0.05	93	258	0	0
Hybrid Car	0	3.40	2.19	5.21	216	603	3.11	8.55

Source : (1) National Institute for reserach and Advancement, Japan

(2) Environment Agency of Japan

As shown in the Table, the electric car is most effective for environmental improvement, followed by the CNG car follows. The hybrid car, is not able to reduce pollutants significantly due to its engine composition .

The electric car is currently being practically used for various purposes, but it is still in the experimental stage for ordinary use on the public roads.

CNG cars have already advanced to the stage of utilization in various countries, as shown in Table 6.29 below. From both the technical and economic points of view, the use of CNG cars should be future promoted to substitute conventional gasoline cars. Since CNG cars will most likely have an advantage over other taypes of gas even in the early 21th century, they have been selected as the immediate object of this study.

Table 6 .29 Situation of CNG Car Usage in the World

Country	Number of Vch.	Number of Station
CIS	470,000	483
Italy	335,000	260
Argentine	150,000	260
New Zealand	60,000	387
Canada	32,550	180
U.S.A	30,000	550
China	1,200	-
Iran	1,200	2
Australia	800	25
Nigeria	504	-
Pakistan	270	1
Indonesia	212	6
Trinidad Tobago	200	1
Japan	105	5
France	100	1
Others	293	16
Total	982,400	2,180

Sources: International Conference Exhibition NGV90, NGV92 &

It is a difficult to specifically set the timing for introducing CNG cars at this moment, and so the following assumptions were made for the study to project their impact on the environment at each projected economic stage.

Assumption-1: Start introduction of CNG cars from 1996.

Assumption-2: Annual supply of CNG cars meet the projected number of new car supply for each year.

Assumption-3: CNG cars substitute all fuel types.

Assumption-4: CNG cars have the same lifespan as the conventional types.

Assumption-5: No improvemments are made in the exhaust system of conventional vehicles.

The estimated pollutant emission in Tehran is presented in Table 6.32. When the share of CNG cars dominates the whole vehicle stock, there will be no more SOx emission, and HC and NOx emission will be reduced to one tenth, CO_2 will be reduced to 80 % even without control. Since it may not be easy to replace all conventional-type vehicles with CNG cars this way, it would be more practical to introduce them first for buses, large trucks and taxies. While the number of CNG stations will be insufficient to respond to the demand of the unspecified numbers of private cars for some time, drives will have better access to special gas stations.

It has been reported that Tehran City already has a plan to introduce 20,000 CNG cars to operate as taxis, and that it has started supplying CNG to 8,000 taxis using 8 gas stations.

6.7 Potentials of Reduction in Pollutants and Considerations on Measures for Environmental Improvement

6.7.1 Main Findings of the study

6.7.1.1 Current Status of Air Pollution in I.R.Iran

(1) In large cities

Past trends of air pollution in Tehran show that the concentrations of main pollutants including lead were higher than the WHO guidelines for the city. For instance, SOx concentration significantly exceeded the WHO guideline of 0.04 - 0.06 mg per cubic meter.

International comparisons also show that Tehran was highly ranked in terms of air pollution concentration . In 1992, Tehran ranked top in the number of days per year when SPM and smoke levels exceeded the critical values , and ranked second in SOx emissions.

According to I.R.Iran's newspaper reports, Mashhad, Isfahan, Shiraz, Tabriz, and Arak are the most polluted cities following Tehran. A report prepared in February 1993 analyzes that 65 per cent of total air pollution in Tehran is caused by nearly two million vehicles moving around in the city. Around one-fourth of the pollution is reported to be from industries, and one-tenth from households.

(2) In the country as a whole

Main emission sources in energy consuming sectors are generally listed as follows:

- Oil fields flaring or burning some 10 to 15% of production
- Petroleum refineries with some 5 to 10% geed loss
- Oil-burning power boilers of ratings higher than 100 t/h
- Gas turbine generators burning low grade (high sulfur) fuels
- Small and medium -sise industries burning low grade fuel oil
- Large scale iron and steel mills
- Big cities with a population of more than one million
- Motor vehicles

Total SOx emission from energy consumption increased about 6 times during the period from 1970 to 1990, according to our calculation. The industry and energy conversion sectors posted extreme growth in emission, and accounted for 60 per cent of total emission from energy consumption in 1990. In addition, the SOx emission volume from the flaring associated gas is estimated to be almost the same as that from total energy consumption in I. R. Iran in 1990.

Total NOx emission from energy consumption increased about 5 times during the same period. The most significant increase in NOx emission was recorded in the transportation sector, which accounted for about 60 per cent of total NOx emission from energy consumption in 1990. It is estimated that NOx emission volume from flared gas is very small compared with that from other sources.

Total CO_2 emission of increased in every energy-consuming sector in accordance with the increase in fuel consumption. CO_2 emission from flared gas is estimated to be equivalent to about 10 per cent of emission from other sources in 1990.

6.7.1.2 Forecasting Emission Volumes

Estimates have never been made on the concentration of air pollution in main cities or areas for the future. This will be one of the most important tasks in the next step of environmental studies in I.R. Iran.

Our estimates of air pollutant emissions show that an increase in SOx emission in the future is signifant especially in the transportation sector. Total NOx emission will also grow significantly in the transport atton sector while it will not increase so rapidly in the industry and energy conversion sectors. The transportation sector will lead other sectors also in terms of increase in CO_2 emission.

The emission of SOx, NOx, and CO_2 from flared gas has not been estimated, mainly because the flaring process will be abandaned when the planned gas sites for the removal of H2S from sour-associated gas are completed and their operation begins.

6.7.2 Technical Potential of Reduction in Pollutants

6.7.2.1 Factors contributing to air pollution

The factors contributingto the emission of SO_x ,NO_x and CO_2 were described in "6.4.2 Factor Analysis". According to the results of factor analysis, the same contributing factor has different effects on the reduction of each pollutant.

a) The fuel switching factor (fuel improvement and fuel conversion) is the greatest contributor to SOx reduction. The sigle biggest contributor is the energy intensity improvement factor.

b) The fuel switching factor and the energy intensity improvement factor are major contributors with regard to NOx emission.

c) The energy intensity improvement is the greatest factor in the reduction of CO_2. The second biggest contributor is the fuel switching factor.

Two kinds of trial calculations are shown below - one is on a macro basis and the other on a micro basis.

6.7.2.2 Estimate of the Technical Potential

(1) Assumption for the Estimation

1) Fuel Improvement

The effect of fuel improvement is evaluated on the basis of the assumption that improvements are made in the three main kinds of liquid fuel--fuel oil, gas oil and gasoline--as shown in Table 6.30 below.

Table 6.30 Assumed Improvement of Fuel in Sulphur Content

(%)

	Before Improvement	After Improvement
Gasoline	0.1	0.004
Gas Oil	0.9	0.2
Fuel Oil	3.3	1.0

The assumed figures for 'After Improvement' are based on current figure for Japan. The figures for 'Before Improvement' are the estimated present status in I.R. Iran.

2) Fuel Conversion

It is assumed that all fuel oil which is currently consumed in I.R. Iran is substituted by natural gas.

3) Energy Intensity

The improvement of energy intensity greatly contributes to the reduction of NO_x and CO_2. This is the only practical way to achieve CO_2 reduction.

Figure 6.53 (a) and Figure 6.53 (b) show past trends of energy intensity in I.R. Iran and Japan. These figures indicate that the primary energy requirement per GDP in I.R. Iran has been increasing continuously since 1971. The figures also indicate that in Japan the energy intensity has decreased 18.59 Kcal/Yen (4,722 Kcal/US$) in 1974 to 11.67 Kcal/Yen (2,964 Kcal/US$) in 1991. 1985 prices were used at exchange rate of 254 Yen/$. The ratio of the reduction is 37%.

Energy intensity in I.R. Iran in 1985 is estimated to be 3,557 Kcal/US$. This figure was derived from the parameters as follows:

Exchange rate:	89.5	Rls/US$
Primary Energy Requirement	412.2	MMBOE
GDP;	15.168x10^12	Rials
GDP per Capita	3,655	US$/capita

Table 6.31 summarizes the energy intensity values for 1985 and 1990 in these two countries.

Table 6.31 Comparison of Energy Intensity

			1985	1990
I.R. Iran	Value @'85 Price	kcal/$	3,577	4,792
	Value @Current Price	kcal/$	3,577	5,476
	Exchange Rate	Rial/$	90	262
	GNP Deflator	1985=100	100	229
Japan	Value @'85 Price	kcal/$	3,187	3,032
	Value @Current Price	kcal/$	3,187	1,781
	Exchange Rate	Yen/$	254	150
	GNP Deflator	1985=100	100	107

Source: APPENDIX "Parameter Table"
EDMC, "Energy Economics Statistic Table", 1993

The US$-based value of energy requirement/GDP depends on the exchange rate, which is difficult to evaluate. According to the table, the energy intensity values in I.R. Iran and Japan in 1990 are 3,032 Kcal/$ and 4,792 Kcal/$, respectively at '85 constant prices.

Supposing that it is possible to improve the energy intensity in I.R. Iran to the level of Japan in 1990, the ratio of reduction or improvement will be 36.7%. On the basis of this review, the potential improvement of energy intensity in I.R. Iran is assumed to be 35%.

(2) Technical Potential of Reduction in Pollutants

1) SO_x

a) Fuel Improvement and Fuel Conversion

Figure 6.54 shows the result of calculations to estimate potential SO_x reduction by fuel improvement and fuel conversion in 1990. The effect of fuel improvement based on the a forementioned assumption is indicted as the fuel improvement case in the figure. The fuel improvement and conversion cases in the figure are summaries of the former two cases.

According to the figure, SO_x emission reduction rates by means of fuel improvement, fuel and a combination of these two measures is expected to 70%, 53% and 86%, respectively. These drastic

Fig. 6.53(a)

Trend of Energy Intensity

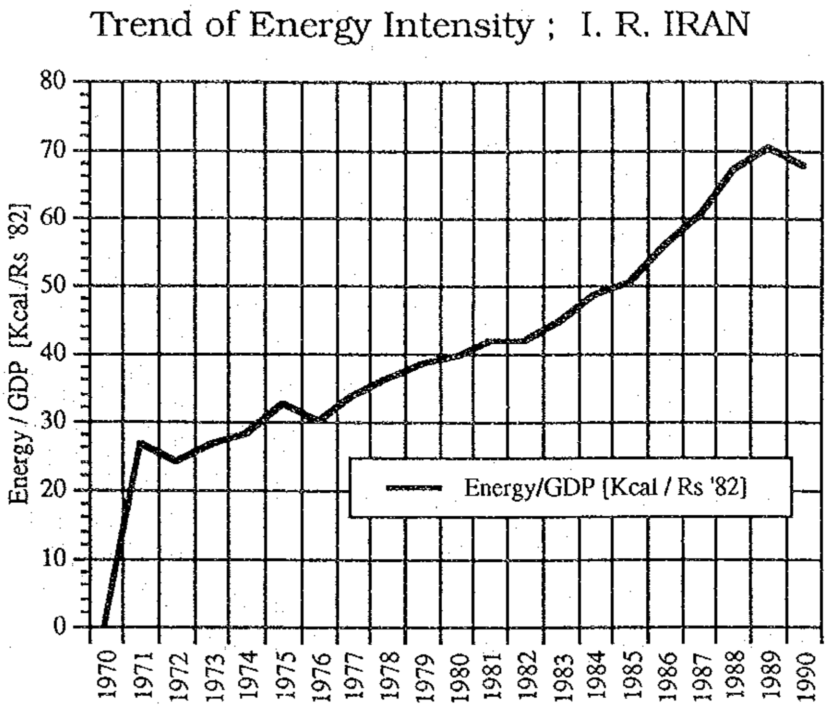


Fig. 6.53(b)

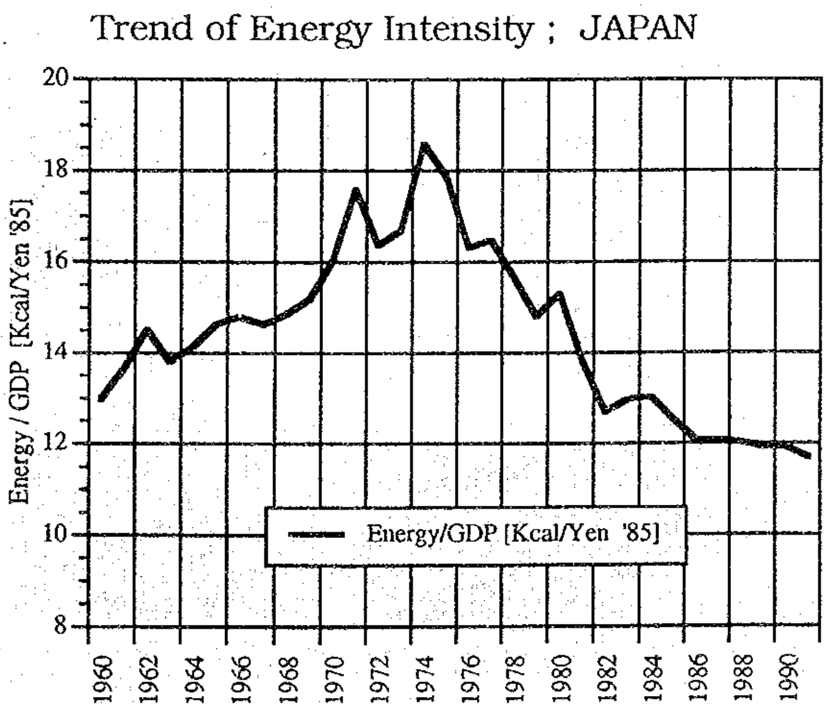
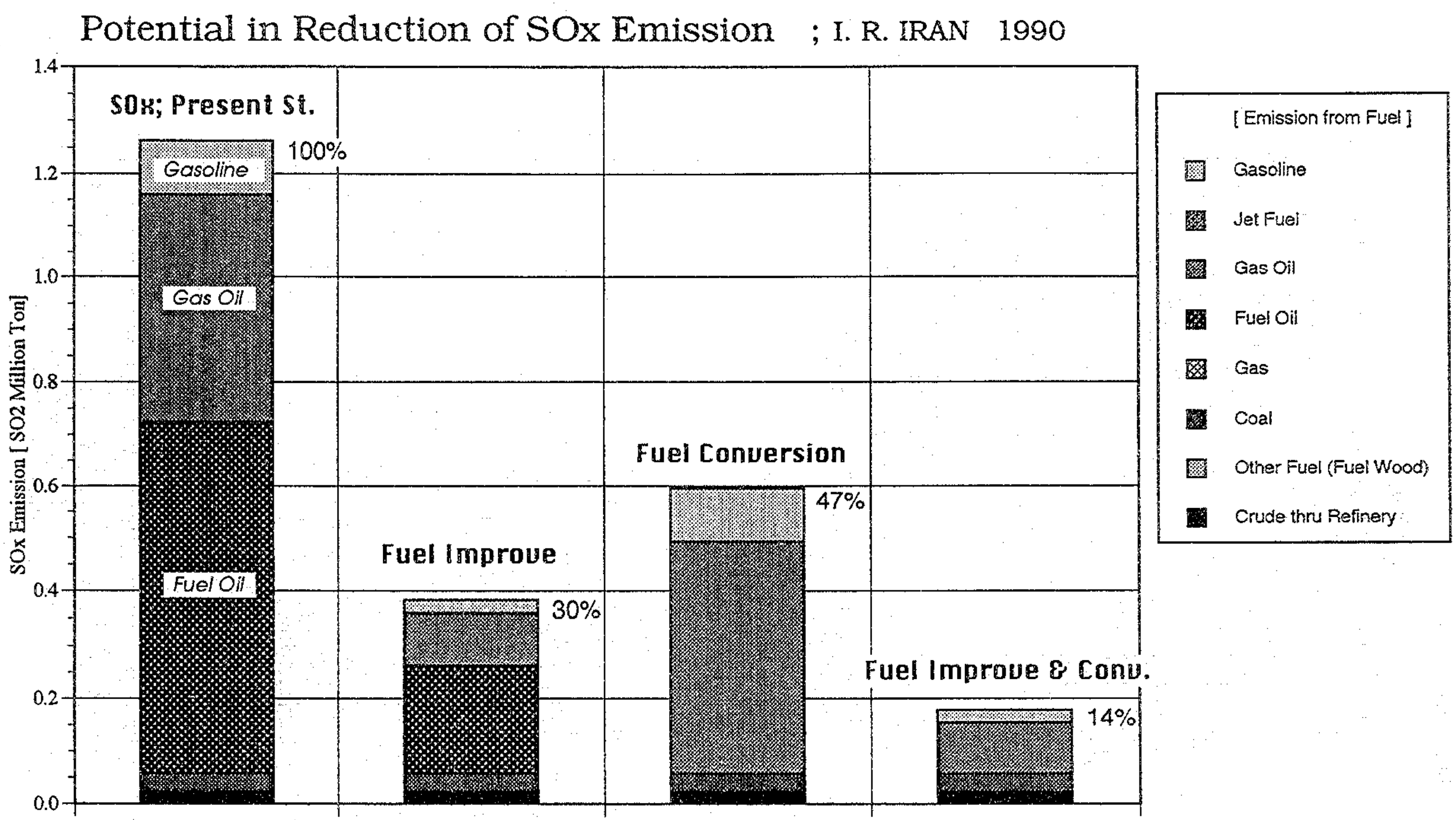


Fig. 6.54



Potential in Reduction of SOx Emission ; I. R. IRAN 1990
SOx Emission [SO2 Million Ton]
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
SOx; Present St.
100%
Gasoline
Gas Oil
Fuel Oil
Fuel Improve
30%
Fuel Conversion
47%
Fuel Improve & Conv.
14%
[Emission from Fuel]
Gasoline
Jet Fuel
Gas Oil
Fuel Oil
Gas
Coal
Other Fuel (Fuel Wood)
Crude thru Refinery

figures show that there is quite a big potential for SO_x emission reduction in the country.

In Japan, the Japanese Industrial Standards (JIS) specify sulfur content in kerosene for home use to be within 0.015%, and the sulfur content of products on the market have actually been reduced to 10 ppm (0.01%). For industrial use, the maximum sulfus content in kerosene and gas oil has restricted to 0.2% since 1992, which all the refineries in Japan are ready to produce. Further reduction of sulfur content in kerosene and gas oil for general use to 0.05% is scheduled to be achieved by 1997. As for heavy fuel oil, there are four grades of sulfur content for different uses, ie. 0.5, 2.0, 3.0 and a maximum of 3.5%.

b) Improvement in Energy Intensity

As discussed before, the improvement in energy intensity is estimated to have stet potential of further reducing SO_x emission by 35%. This factor together with the other two factors--fuel improvement and fuel conversion--will improve the overall SO_x emission reduction from 86% to 91%.

2) NO_x

a) Fuel Conversion

Figures 6.55 shows the effect of fuel conversion on NO_x emission. The improvement of burning efficiency is not considered in this study. Supposing that all the requirement of fuel oil is provided with natural gas, the effect on NO_x reduction is estimated to be 9%. The result agrees with the Japanese experience which indicates the main contributors of NO_x reduction are combustion modification and the exhaust gas control.

b) Energy Intensity

Improvement in energy intensity has a remarkable effect on NO_x as well as SO_x emission reduction. The potential improvement in energy intensity, which is estimated to be 35%, will bring about 41% of total NO_x emission reductio

3) CO_2

a) Fuel Conversion

Figure 6.56 shows the effect of fuel conversion on CO_2 emission. Supposing that natural gas satisfies all the requirements concerning fuel oil, its effectiveness CO_2 in emission reduction is estimated to be 6%.

b) Energy Intensity

The main contributor to CO_2 emission reduction is, of course, improvement in energy efficiency. The potential improvement in energy intensity, which is estimated to be 35%, will bring about 39% of total CO_2 emission reduction. Reviewing the consideration discussed above, the potential reduction rates of emitted pollutants and CO_2 are summarized as follows.

Table 6.32 The Potential Reduction of Pollutants and CO_2 (%)

	Fuel Improvement and Fuel Conversion			Energy Intensity Improvement	Overall Reduction
	Improvement	Conversion	Total Effect		
SO_x	70	86	86	35	91
NO_x	-	-	9	35	41
CO_2	-	-	6	35	39

6.7.2.2 Effects of Fuel Conversion to Natural Gas in Power Plants

(1) Assumptions

Following assumptions are made for the estimation:

1) All steam turbine plants using fuel oil and gas oil are to be converted to use natural gas.
2) All gas turbine plants using gas oil are to be converted to use natural gas.
3) All gas turbine plants using natural gas are to be renovated into gas combined cycle plants.

Actual data on the operation of power plants in I.R. Iran as of 1992 are shown in Table 6.33.

Fig. 6.55

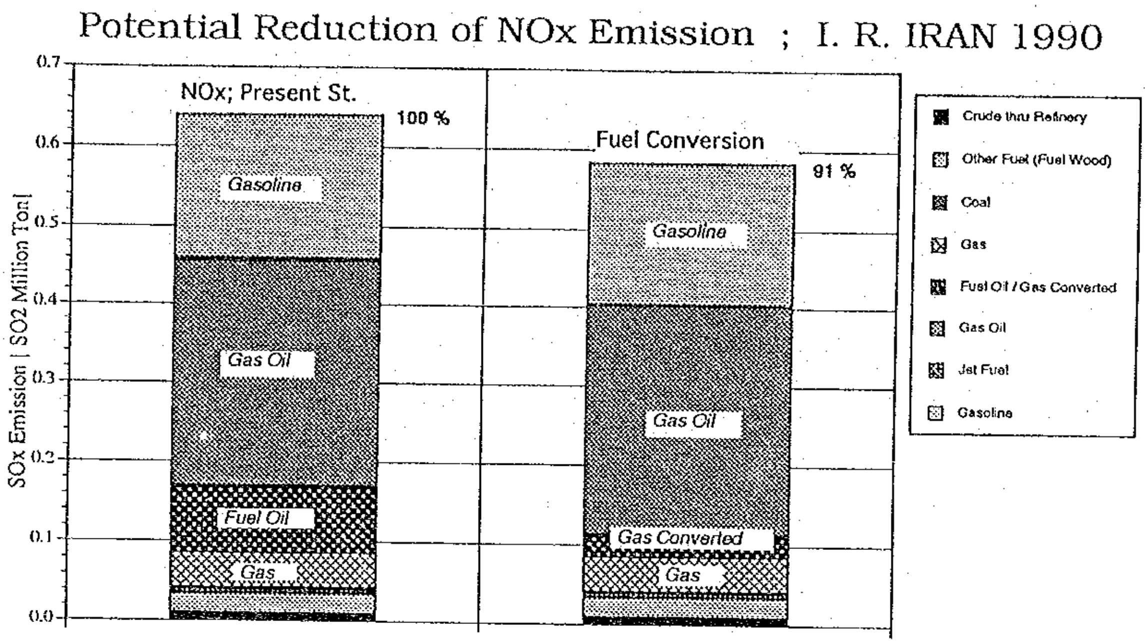
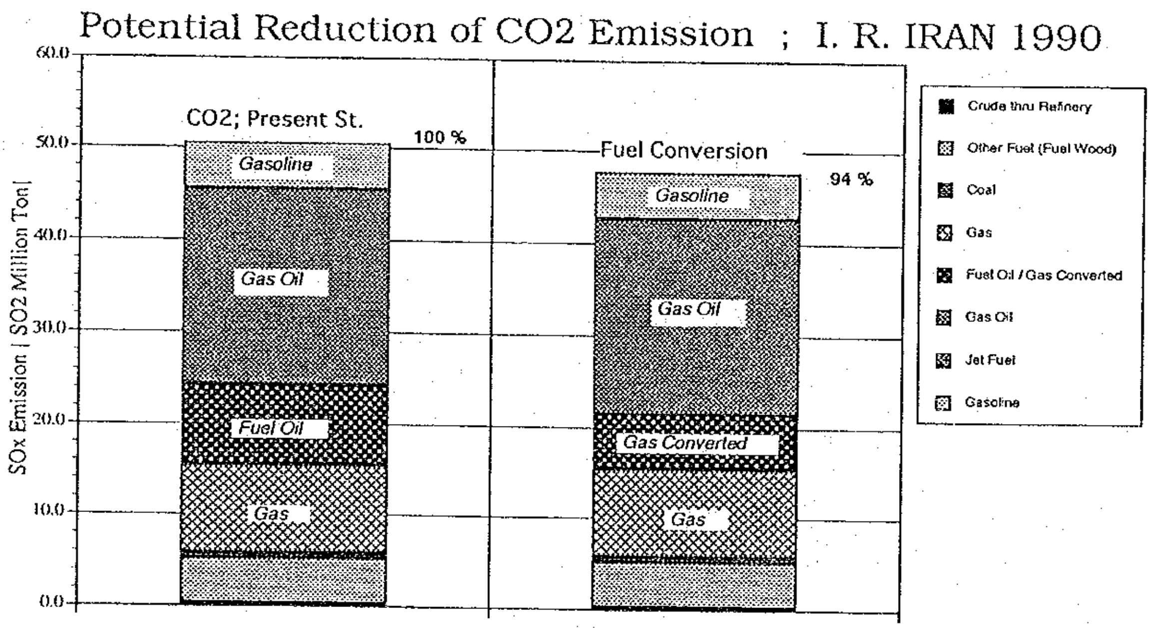


Fig. 6.56



Actual data on the operation of power plants in I.R. Iran as of 1992 are shown in Table 6.33.

Table 6.33 Actual Operation Data of Power Plants in Iran (1992)

<Steam Turbine>

	Total	Fuel Oil	Gas Oil	Natural Gas
Capacity (MW)*	5,373 MW*			
Fuel Consumption (PJ/y)	418 PJ/y	187 PJ/y	1 PJ/y	230 PJ/y
Production (GWH)	42,362 GWH			
Therm Efficiency	34.2 %			
SO_x Emission (million ton/y)	291 Mt/y	290.5*	0.5*	0.005*
NO_x Emission (million ton/y)	69.4 Mt/y	45.6*	0.7*	23*

<Gas Turbine>

	Total	Fuel Oil	Gas Oil	Natural Gas
Capacity (MW)	1,378 MW*			
Fuel Consumption (PJ/y)	157 PJ/y	0 PJ/y	26 PJ/y	131 PJ/y
Production (GWH)	10,866 GWH			
Therm Efficiency	22.9 %			
SO_x Emission (million ton/y)	12 Mt/y	0*	11*	1*
NO_x Emission (million ton/y)	31 Mt/y	0*	17*	14*

*= calculated value (Capacity's value includes 10% reserves)

(2) Effects of Fuel Conversion on SOx and NOx Emission

As can be seen in Table 6.34, SOx emission can be reduced by 291 million tons annually as a result of the aforementioned conversions, and NOx emission can be reduced by 53 million tons as a result of conversions and renovations. The latter figure includes the 9 Million tons by which NOx emission can be reduced through energy (natural gas) saving accomplished by renovating the plants to a combined-cycle system.

The total reeducation rate for SOx and NOx emissions are 98 per cent and 51 per cent, respectively.

Table 6.34 Effects of Fuel Conversion on Pollutant Emission

	SOx Reduction	NOx Reduction	Energy Saving
<Steam Turbine> Fuels Conversion	287Mt/y (△98%)	29Mt/y (△41%)	
<Gas Turbine> Fuels Conversion	11Mt/y (△92%)	15Mt/y (△48%)	
<Gas Turbine> Renovation Combined Cycle			76PJ/y (△48%)
Effects by Energy Saving above		9Mt/y	
Total	298Mt/y (△98%)	53Mt/y (△53%)	

6.7.3 Considerations on Measures for Environmental Protection

Based upon the findings of this study, the following items are concepts to be considered by the Government of I.R. Iran to improve the environment.

(1) Establishment of a Monitoring System

The establishment of a monitoring system is indispensable in hammering out realistic and concrete polices for environmental protection. In fact, its development is already under way especially in Tehran. Technical cooperation with Japan to pursue environmental studies started recently, and is expected to contribute to the establishment of a monitoring system.

(2) Acceleration of Energy Conservation

As mentioned in 6.7.2, energy conservation will have a large effect on reducing the emission of pollutants including CO_2. The measures for energy conservation which are mentioned in the Chapter 5 will also contribute to improving the environment. One of the most important measures for energy conservation is the proper maintenance and operation of factories, plants and vehicles.

Since the transportation sector will account for a larger share particularly in the emission of SOx and NOx, accelerating energy conservation in this sector is very important.

(3) Conversion of Petroleum to Gas

As mentioned in 6.7.2, converting the fuel type from petroleum to gas will contribute to reducing many pollutants in all sectors including road transportation. The utilization of CNG and LPG as fuels for vehicles has already been hammered out in I.R. Iran, although their scale of the utilization will not be so large for the time being.

On the other hand, the conversion cost will not be small and it might be necessary to provide some strategies for proceeding with the conversion. From this point of view, priority should be placed on power plants and large factories whole fuel consumption is large.

(4) Improvement of Refinery Configuration

In the existing refineries in I.R. Iran, there are no hydro-desulfurization units for removing sulfur from gas oil and fuel oil except for some isomax units. These predicts are distributed to users without further removal of sulfur. Under these circumstances, the modernization of refinery configurations should be subject to discussion in light of upgrading the products that cause less SOx emission as well as controlling their product yields to meet grate market demands.

In reviewing refinery configuration, each refinery shall be classified into two major categories--

fuel upgrading refinery and conversion refinery, even in which sulfur contents are removed in the process of converting heavier fractions to lighter ones.

(5) Measures for Efficient Driving of Vehicles

Proper maintenance and operation of vehicles can contribute to reducing air pollutants not only indirectly through reducing fuel consumption but also directly through the more efficient fuel combustion. HC and smoke are two typical pollutants which are generated by lacounplete combustion of fuels.

As cited from a report in 6.3.3.2, incomplete combustion is said to be the result of a shortage in spare parts and due to the attitude of Tehran, but the lack of skills and efforts for the proper maintenance of vehicles must also be considered important causes for incomplete combustion.

(6) Measures against Flared Gas in Oil Fields

SOx emission from the flared gas is estimated to be the same level that from total fuel consumption in I.R. Iran. As mentioned already, the associated gas which has a high H_2S content must be flared in orde it to become usable.

The planned facilities to remove H_2S from sour associated gas and thus make it usable it are expected to complete as soon as possible.

7. Conclusion

7.1 Summary and Findings of the Study

In the process of comprehensive energy studies, a large amount of data on energy demand in social and economical sectors are collected and analyzed and rational use of energy in various sectors was studied. In this chapter the general conclusion of the study is being outlined.

Conclusion of the results of the comprehensive energy studies is based on the fact that energy policy is considered as a means of maintaining a framework for establishing optimal balance between energy demand and supply based on the competitiveness of consumption and supply of energy carriers, and the economical and social cost of energy use will be kept at minimum level. In this way energy policy and energy economy is to contribute to the establishment of an energy supply system, with the help which the following objection would be realized.

a) Useful energy demand of all social and economical sectors and citizens in all parts of the country will be met.
b) The required useful energy will be supplied with maximum efficiency and effectivity; and the cost of energy supply shall be minimum in the long run.
c) Energy sector will be compatible with the social values and sustainable development of the country.
d) Health damages and environmental pollution will be kept at the lowest level.
e) Meeting the living requirements and improving the living condition of future generations will be considered.

Based on the above criteria, the major conclusions of the study are summarized as follows:

1. Economic development and improvement of the living standard of the poor is associated with rising useful energy demand. Useful energy demand is to increase from 878.7 PJ/a in 1994 to 1,011.5 PJ/a is 1999 and 1,908.5 PJ/a in 2021. According to different scenarios, the range of variation of useful energy demand is found to be 1,011.5 to 1,342.5 PJ/a in 1999 and 1,629.6 - 2,423.8 PJ/a in 2021.

   To meet the useful energy demand, restructuring of the energy supply system will be required. In the case of "business as usual" and continuation of the present situation (i.e. when energy is heavily subsidized), consumption of final energy increases to 628.9 MBOE/a in 1999 and

1009.8 MBOE/a in 2021. On the other hand, when the subsidization of energy prices is avoided and energy carriers are delivered to the final consumers with a price equivalent to their long-run marginal cost, the final energy consumption rises from 506.6 MBOE/a in 1994 to 552.7 MBOE/a in 1999 and 961.2 MBOE/a in 2021. In this scenario, it is also assumed that the opportunity cost of oil underground would be zero.

When the opportunity cost of oil is considered as equal to the export prices of crude oil, final energy consumption reaches to a level of 503.0 MBOE/a in 1994 and increases to 549.8 MBOE/a in 1999 and 959.4 MBOE/a in 2021. When the two cases of with and without considering the export value of crude oil underground are studied, it is realized that when due consideration is given to the value of oil underground, final energy consumption is reduced by 0.52% and 0.18% in 1999 and 2021 respectively and the share of natural gas in primary energy consumption rises more rapidly.

When improvement of the efficiency of energy processing, conversion, transportation, distribution and consumption systems is pursued, final energy consumption decreases to 490.9 MBOE/a in 1999 and reaches 673.8 MBOE/a in 2021. When this case of energy management and rational use of energy is compared with the reference scenario, one observes that the final energy consumption may be reduced by 10.71% and 29.24% in 1999 and 2021 respectively. Energy management leads to a reduction of primary energy consumption by 12.31% and 31.67% in 1999 and 2021.

2. Development of the structure of the energy supply system indicates that utilization of hydro power potentials in various parts of the country is a necessity for lowering the cost of electricity supply and decreasing the environmental pollution.

   In eastern part of the country, consumption of coal in industrial furnaces increases in the period 2009 to 2021 and coal provides an economical alternative for supply process heat. Therefore, a detailed evaluation of coal reserves and utilization of clean coal is an important step in the process of optimal development of the energy supply system.

   In the next two decades, when the economy grows more rapidly (with an average annual growth rate of more than 5%/a) and the prices of crude oil increases to $30/bl in 2021, it is found that non-fossil energy sources provide an optimal option for supply of domestic energy needs of the country. This indicates that R&D activities in the area of non-fossil energy should be organized and efforts should be made to build up power plants using non-fossil energy in the next two or three decades.

3. Evaluation of energy export for the purpose of meeting the foreign exchange requirement of the

country indicate that export of crude oil will continue to have a higher share in energy export; but the share of petroleum products in energy export shows a rising trend. It is also found that export of natural gas through the eastern regions of the country and to Pakistan and India provides an appropriate option. In general, structure of energy export develops in such a way that export of petroleum products and natural gas increases gradually.

4. Economic development is greatly influenced by the energy consumption in different sectors. Saving in energy consumption leads, on the one hand, to reduced investment of the energy supply system; on the other hand, it enhances the potentials of energy export in general and oil export in particular. Optimal consumption and rational use of energy in the domestic market provides a reliable option for increasing of GDP per capita and improving the living condition of the population. Management of exhaustible energy resources indicate that sustainable economic development and reducing the dependency of the economy on the changes in the international energy market can be the outcome of the optimization of production and consumption of energy carriers.

5. Comprehensive analysis of the development of energy system indicates that meeting useful energy requirement in social and economical sectors is feasible in the long run, and its realization is not necessarily associated with rapid increase in final and primary energy consumption. In other words, economic development and improvement of the living standards of the population may be achieved with the present level of per capita final and primary energy consumption. It is observed that only in the case of rapid economic growth a rising trend of per capita primary energy consumption may be expected in the next one and half decades. It is realized that adjustment of energy demand and improving the efficiency of energy supply shall lead to a situation, where increase in per capita final and primary energy consumption will not be a necessity.

   Evaluation of the trend of final and primary energy intensity indicates that economic growth does not necessarily lead to a higher energy intensity. In fact, economic development is subject to stabilization of energy intensity and reduction of energy intensity would result in higher economic growth. Therefore, two main important short- and long-term objectives may be identified in the energy sector as follows;

   a) To stabilize per capita final and primary energy consumption at a level of 8.17 and 11.87 BOE/a respectively;

b) To increase the energy productivity (or reduce energy intensity), so that the primary energy intensity would decline by an annual rate of 0.48%/a during the second five years development plan.

6. Reduction of primary energy intensity requires that a policy of rationalization of energy use in social and economical sectors and optimization of energy supply system and better management of energy resources is pursued and the useful energy requirement of the society is met with minimum losses. Analysis of energy consumption is service and production sectors and households reveals that there is a considerable potential for rational use of energy and its realization can be a major element of a comprehensive energy policy. Detailed evaluation of the rational use of energy in production and service sectors and formulation of action plans for energy conservation requires that development of energy data-base and preparation of R&D programms in the area of rational use of energy are considered seriously.

7. Implementation of a policy of rational use of energy and reduction of energy intensity through improvement of energy efficiency of the economic system would result in saving capacities, and consequently capital, in the energy supply system. In this case, capacities of power plants would increase from 31932 MW in 1999 to 46460 MW in 2021 and throughput into the refineries would remain constant at the level of 1.4 MBOE/a in the period 1999-2021. Therefor, rational use of energy would lead to a reduction of the capacity of refineries by 9.11% and 43.6% in the years 1999 and 2021 respectively compared to the case of "Business As Usual". Hence, following the rational use of energy, the potentials of the economy will develop, and large resources would be available for the rapid development of non-energy sectors of the economy, that otherwise should have been allocated to the energy supply.

8. Development of energy demand and supply is associated with the emission of pollutants and increased consumption of fossil energy carriers is accompanied by rising emission of pollutants. Emission of CO_2 increases with a rate of 2.6 %/a in the period 1999-2021 and it reaches a level of 245 million ton in 2021. Rising trend is also observed by SO_2 and NO_x. Emission of SO_2 amounts to 1,330 kt/a in 2021. Amount of NO_x emitted in 1994 is 1,354 kt/a, which increases to 2,946 kt/a in 2021.

Controlling the emission of pollutants leads to a structural changes in the energy sector. Energy conservation in the consumer sectors together with rapid utilization of clean energy sources provide the most economical and reliable option for preserving the environment. When the emission of CO_2, SO_2 and NO_x is controlled, so that the per capita emission of the pollutants in the I.R. of Iran in 2021 would not exceed the present level of per capita emission rate in Japan, it is realized that energy saving in the consumer sectors by 5.8% in 1999 and 16.8% in 2021 would be necessary. Such a measures would provide the most economical means of environmental protection. It would be possible to reduce the emissions of CO_2, NO_x and SO_2 in the year 2021 by an amount of 72.4 million ton, 118.1 kt/a and 559.2 kt/a respectively, compared with the emission level in the Reference case of without pollution control.

9. Energy market in the I.R. of Iran has been distorted extensively. Subsidization of energy is a major obstacle of rational use of energy. Energy carriers are supplied with prices that are much below their marginal costs. This situation has led to rapid increase in energy consumption and depletion of exhaustible energy resources is accelerated.
Energy is mainly subsidized to help the poor, utilize the relative advantages of the economic system and control the inflation. But the analysis of the real situation indicates that delivery of energy with prices lower than the marginal cost of production and supply of energy carriers has hindered the realization of the aforementioned objectives. Economic resources are invisibly allocated to households and economic sectors through energy subsidization and the basic criteria for the distribution of the resources has been the level of energy consumption. Social groups and economic sectors that consume more of high quality energy carrier, benefit the most from the energy subsidization. The fact is that the invisible allocation of resources through energy subsidization can not be considered as a rational policy of more equitable distribution of income, which households with a better living condition and accessibility to modern household appliances have a higher share in receiving invisible income through energy subsidization than poor households; Supply of energy with prices much lower than its marginal cost distorts the competition between production factors (labour and capital) and energy. In this case, appliances and processes with low efficiency and low quality, that have high operation cost but low capital cost, will be preferred. Outcome of this situation would be promotion of high energy consumption and domestic production of equipment and machinery with low quality. As a consequence of this situation, potentials of the competitiveness of domestic products in the international market will be limited. Subsidization of energy results in misallocation of economic resources, reduction in potentials of the competitiveness of the economic system, inappropriate distribution of economic resources among the households and limitation of economic potentials of the country.

10. Establishing optimal balance of energy demand and supply and restructuring the energy management in the country makes it necessary to develop energy policies on the basis of a

better and deep understanding of energy issues of the country and comprehensive evaluation of energy production and consumption patterns. For this purpose, organization of goal oriented energy R&D activities is considered as a necessary and urgent step.

Further development of energy studies in the area of energy information system, energy demand management, optimization of energy supply system, optimal utilization of energy resources, and a better understanding of the mechanisms of energy pricing and its determinants in the world energy market are important elements of energy studies that ought to be considered seriously.

7.2 A Priority Plan
-- For Promoting Rational Use of Energy and Energy Conservation --

The main results of our collaborative studies strongly indicate that promoting the rational use of energy and energy conservation is one of the most important policies in I. R. Iran, as mentioned above. Concrete policies to encaurage energy conservation in the social and economic sectors are essential.

However, data and information relevant for adopting and implementing the policies are insufficient so that reliable and realistic measures can not easily be drawn up at this moment. Consequently, more detailed studies to promote rational use of energy and energy conservation are necessary to formulate future energy policy in I. R. Iran.

Our suggestions on the studies are as follows:

The main subject of the study is to establish a basis for the rational use of energy at micro level in order to provide detailed information for energy management in the process of modernization of the economy in the Islamic Republic of Iran. The following items will be given due consideration in the course of this study.

a) Establishment of Energy Data Base for Studying Rational Use of Energy

The different production and service processes will be analyzed and studied for representing the flow of energy in each process and/or sector, and a measurement of the energy flow in different processes would be carried out, in order to establish a reliable database for micro analysis of energy conservation and the rational use of energy. Then, it should lead to identifying the technical and economic potentials of saving energy, and to study the appropriate measures for optimal utilization of the potentials in the social and economic sector in the Islamic Republic of Iran.

b) Study of Measures for Energy Conservation

- Reduction of Unnecessary Consumption of Energy

  Unnecessary consumption of energy is the amount of consumed energy carriers, which does not affect the production of goods and services. It is intended to examine the usage of energy in different processes and identify the measures that could prevent the unnecessary consumption of energy carriers.
- Improvement of the Effectivity

The energy efficiency of the production and service sectors will be studied, and the effect of maintenance and the state of the technologies on the use of energy shall be examined. On the basis of this analysis, the measures for improving the maintenance of the systems and replacement of the obsolete technologies will be identified.

- Recovery of Energy

  Recovery of heat in different processes and utilization of the recovered energy will be studied. Technical and economical potentials of this alternative will then be evaluated.

- Electric and Gas Load Management

  Electric and gas load management in the economic sectors will be studied in detail and measures contributing to the peak shaving and the more efficient utilization of the capacities of the power plants and gas supply facilities shall be evaluated.

c) Estimates of Energy Conservation Potentials

- Estimates of Technical Potentials

  The energy intensity, i.e. amount of energy used for a unit of production in economic sectors, will be studied, and the results will be compared with the energy intensity of similar processes in Japan and other industrialized countries.

- Estimates of Economic Potentials and Impacts on Labor Productivity

  The investment cost for implementing the measures of energy saving will be examined, and the impact of energy conservation and rational utilization of energy on the labor productivity will be analyzed

- Optimization of Energy Intensity

  Thereafter, conclusion will be drawn on the optimization of the energy intensity with identifying the policy options and instruments for development of the country.

d) Preliminary study of Appropriate Policies

On the basis of this project, the framework of policies for energy management will be outlined. Thereby, the appropriate measures for energy conservation will be described, and the main features of the programs for encouraging energy conservation, energy pricing scheme, modernization of the technologies and improvement of institutional arrangements will be studied.

7.3 "Action Plan"
-- Basis for Sustainable Implementation of the Plan --

It can be suggested that the "Action Plan" should be considered as the basis for sustainable implementation of the plan for promoting rational use of energy and energy conservation even in advance of making the detailed studies mentioned on 7.2 above. Tentative and preliminary studies show that several aspect including policy, institutional, financial, and human ones should be taken into consideration.

a) Basic policy direction should be considered, formulated, and declared in order to lead people to be willing to promote energy savings. Pricing policy is one of policies indispensable to promoting rational use of energy and energy conservation and taxation is another to be considered seriously. Research, development, and demonstration (R. D. & D.) policy also should be formulated for future technology for promoting energy conservation.

b) Institutional Arrangements
Identification of the measures for energy demand management will be followed by the analysis of the management system in the energy sector. Thereafter, development of institutional infrastructure for implementation of rational use of energy will be examined.

(i) Establishment of Energy Information System
In the process of the development of the project, the necessary data and information for the analysis of energy management data and information system will then provide a scientific basis for promoting rational use of energy and helping to evaluate various policy options of energy management in the Islamic Republic of Iran.

(ii) Development of Educational Infrastructure for Training Energy Managers
Implementation of the measures for energy conservation and rational use of energy is conditioned by the fact that well trained energy managers are employed in different sectors. To this end, it is intended to establish a department within IRPD where trainings of both classroom and practical skills on energy management will be employed.

(c) Financing Arrangements
Financial supports by the government are necessary for promoting energy savings,

including providing companies and others with long-term and low interest money. Tax credit as well as depreciation allowance have also the effect of financial aid to those who will try to promote energy savings. A special fund can be one of devices which will finance such financial supports.

(d) Human Development

Human development is also necessary for promoting rational use of energy and energy conservation, including the way mentioned b) - (ii) above. Effective and sustainable implementation of the policy needs such sorts of human resources as researchers in institutes, administrators in the governments, managers and workers in companies or factories who are well trained and motivated for energy conservation.

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