CHAPTER 4

DATA ANALYSIS AND DISCUSSION

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4.1. Energy Analysis

The following analysis on the energy consumption of Malaysia aims to demonstrate how the increasing trends, rates and various external factors that affect them will contribute to the air pollution problems in Malaysia.

Before discussing energy supply and consumption patterns in Malaysia, it is useful to put the country in perspective by comparing its energy consumption with that of the other countries in the world. In general, energy consumption of almost every country grows throughout the years **[Figure 4.1]**.

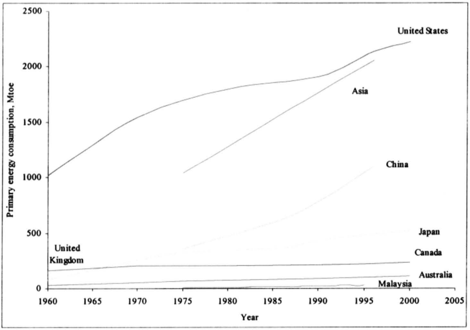


Figure 4.1. Primary energy consumption of various countries (million tonnes oil equivalent), 1960 -2000.

The world's energy consumption grew by an average of 3.3 per cent per year between 1960-1990 but the growth was very different in developed and developing countries *(Goldemberg, 1996)*. In this regard, Malaysia's primary energy consumption has increased from 7.6 million tonnes oil equivalent (mtoe) in 1975 to 30.89 mtoe in 1995.

Countries with smaller population size such as Malaysia, Singapore and Australia were also noted to be consuming less energy in total as compared to countries with larger size of population. However, the total amount of energy consumed by countries like Indonesia, Thailand and Turkey has turned out to be far lesser to that of Japan and United Kingdom even though the later has a smaller size of population **[Figure 4.2]**.

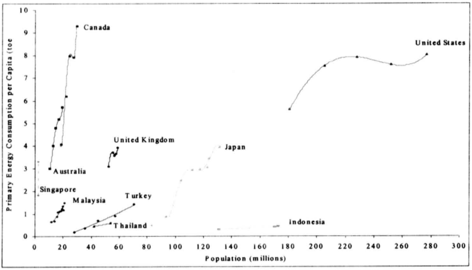


Figure 4.2. *Primary energy consumption per capita (toe per capita) versus population (millions) of various countries.*

Figure 4.3 shows that, on a per capita basis, energy use in developed countries (with higher per capita income) always surpass that of the developing countries. Energy consumption per capita of Malaysia was about 1.11 toe in 1990 i.e. only about 20% of the value reported for Australia in the same year.

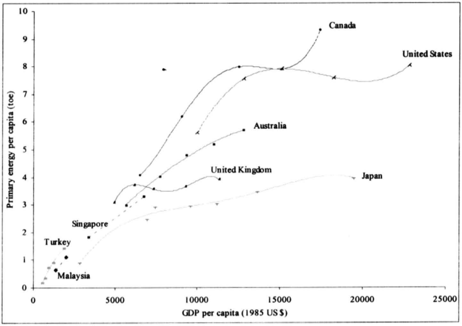


Figure 4.3. *GDP (1985 US $) per capita and associated primary energy consumption per capita (toe).*

This is because the increase of consumption is a result of a combination of unprecedented population growth and equally remarkable growth in per-capita use of the industrial energy. Ang (1986) reported that there has been in relative importance a decline in agriculture with a rise in manufacturing in all the ASEAN countries. This structural change of production, which is associated with industrialisation, has led to a more rapid increase in energy demand than would have been the case had there been no change in production structure.

The change in production structure has also introduced urbanisation which in itself is an energy intensive process. The share of urban population is closely related to the sectoral composition of employment, which in turn follows closely to the structure of production. As the shift of production from primary sectors to manufacturing occurs, there will be migration from rural to urban locations. The process which is currently taking place in developing countries has been experienced and well established in the developed countries.

In addition, the urban population has greater access to the use of electricity and other commercial fuels than the rural ones, particularly in transport and household energy uses. As such, it would be interesting for the developing countries, including Malaysia, to raise the question as to whether they would allow their countries to follow the so-called western lifestyle which are associated with high energy intensities of food production and distribution, personal transport and high consumption. This again, of course, relies very much on the awareness of the consequences brought about by such developments.

A different picture emerges in regard to the average annual growth rate of primary energy consumption and its per capita value as is evident from **Figure 4.4** and **Figure 4.5**. The rates are noted to be decreasing between 1970-1990 for developed countries such as the United States, United Kingdom, Canada and Australia.

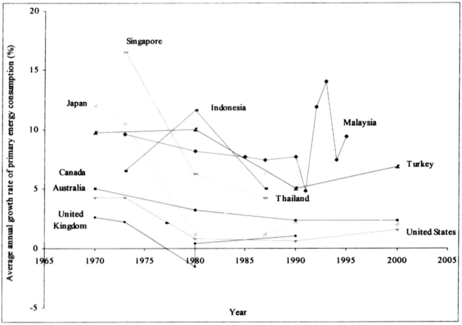


Figure 4.4. ***Comparison of average annual growth rate of primary energy consumption between countries.***

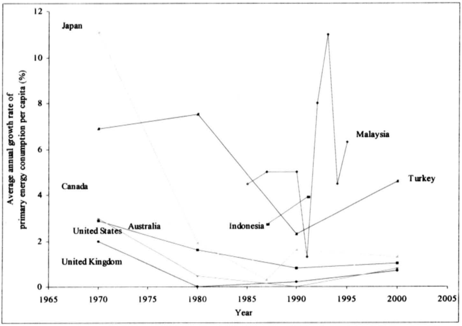


Figure 4.5. ***Average annual growth rate of primary energy consumption per capita (%) for various countries.***

Consumption has, however, been growing at high rates in the developing countries, and the trend is believed to be continued during the next few decades for the following reasons: population growth of about 2 per cent per year which, in the aggregate of all developing countries, has been responsible for 50 per cent of the annual growth rate of energy consumption, and; steady economic growth which, in most parts of the developing world (with the exception of some African countries), is a result of political independence, integration into the world economy and access to information via radio and television *(Goldemberg, 1996).*

Although the average energy consumption per capita figure is relatively low in the developing countries, the potential growth of energy requirement, especially in Asia, is high *(Kato, 1996; Shrestha et. al., 1996).* In short, if the present fuel mix remains unchanged, the evolution of the energy sector in these countries, including Malaysia, has important environmental implication and will be reflected in the emission of pollutants, particularly sulphur dioxide, nitrogen oxides and carbon dioxide from the burning of fossil fuel.

It can be seen in **Figure 4.6** that there exist a strong correlation between energy demand and economic output *(Ibrahim, 1997).* Those countries high in per capita income generally consumed more energy per head, and those with a higher economic growth also experienced a more rapid increase in primary energy consumption.

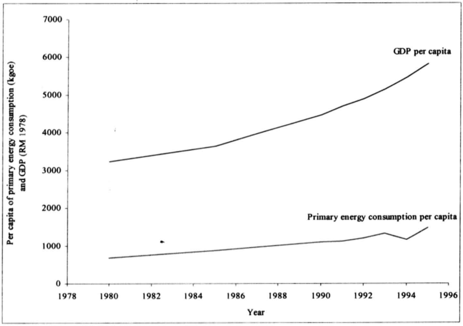


Figure 4.6. Per capita value of primary energy consumption (kgoe) and GDP (RM 1978) in Malaysia.

In majority of the developing countries where commercial energy consumption per capita is below 1 toe per year, illiteracy, infant mortality and total fertility rate are high, while life expectancy is low. Surpassing the 1 toe/capita barrier seems, therefore, an important instrument for development and social change **[Figure 4.7]**. A low energy consumption is not, of course, the only cause of poverty and underdevelopment but it is a good proxy for many of its causes, such as poor education, bad health care and the hardship imposed on women and children.

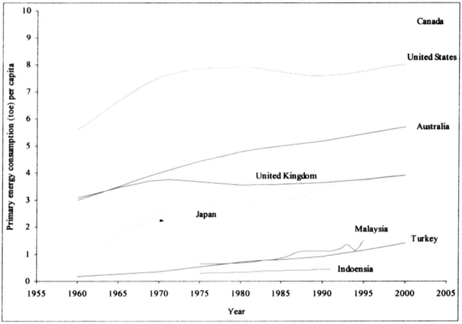


Figure 4.7. Primary energy consumption (toe) per capita of various countries.

As commercial energy consumption per capita increases to values above 2 toe (or higher) in industrialised countries, social conditions improve considerably. Average consumption per capita in OECD countries in 1990 was reported to be about 5 toe a year *(Goldemberg, 1996).*

In fact, the ratio between energy use and an economy's GDP, which is a measurement of the value of goods and services produced in a country in a year, is commonly termed the energy/GDP ratio *(Ibrahim, 1997).* The ratio is a measurement of energy intensity, but comparisons of energy intensities in different countries are subject to the limitations concerning monetary valuations of GDP. The energy/GDP ratio is merely a preliminary indicator of the demand for energy.

It is a shortcut approach and serves as a preliminary approximation of how energy demand may be related to economic activity, standard of living, and stock of energy-using equipment *(Ibrahim, 1997)*. Although admittedly a very rough indicator, energy intensity has some attractive features: while energy and GDP per capita vary more than one order of magnitude between developing and developed countries, energy intensity does not change by more than a factor of two.

The evolution of the energy intensity over time reflects the combined effects of structural changes in the economy – built into the GDP – and changes in the mix of energy sources and the efficiency of energy use – built into the primary energy consumed. The factors that determined the evolution of the energy intensity are dematerialisation, fuel intensity and recycling *(Goldemberg, 1996)*.

Dematerialisation of the economy means using less material for the same end objective, an example of which is the use of fiberglass to replace copper for telephone transmission. In the US, the share of basic materials in the GNP has decreased by almost 30 per cent since 1970. Fuel intensity measures how much energy is needed to manufacture a given product: for example, the fuel per ton of steel, of the electricity per kilogram of polyethylene. Recycling, on the other hand, broaden the concept of dematerialisation and, if pushed to its limits, would contribute effectively to a decrease in pollution although, in a number of cases, it is not cost effective.

Energy intensities of most of the industrialised countries are decreasing while it has been increasing in the developing countries, although the value, in general, are smaller than the industrialised countries. **[Figure 4.8]**.

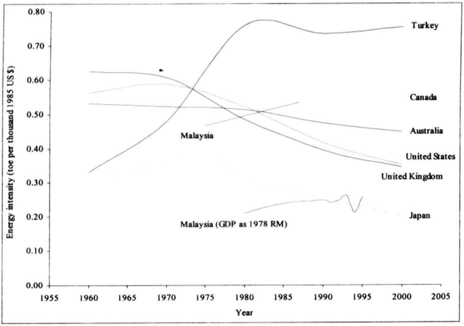


Figure 4.8. *Comparison of energy intensities between developed and developing countries.*

The decline of energy intensity in the developed countries is due to further technological advance, leading to improvement in energy efficiency, and to further structural change towards less energy intensive sectors *(Ibrahim, 1997)*. The underlying rising trend and the actual changing relation between the developing countries may be linked to the following interrelated factors: fuel substitution, structural change of production and rising transport energy use *(Ang, 1986)*.

Energy is not a single commodity; there is scope for substituting one form of energy for another. For instance, the substitution of commercial for non-commercial fuels in final energy use in the developing process which primarily took the form of substituting kerosene and LPG for wood in household energy use.

The steadily declining share of non-commercial energy in total energy use implies for any percentage rate of growth of commercial energy consumption there has been a greater percentage rate of growth of commercial energy consumption. In addition, fuel substitution among commercial fuels will also lead to changes in the overall energy end-use efficiency and hence energy-output ratio.

If GDP is broken down by producing sector, the energy intensity (that is, energy demand per value-added) for the manufacturing sector is generally several times higher than that for the agricultural sector. At a higher level of disaggregation, the manufacturing industry comprises a dozen or so many sectors whose energy intensities vary widely. The engineering and textiles sectors are low in energy intensity, while iron and steel, non-metals and petrochemicals are high in energy intensity. The changing importance of different sectors in industry, or structural change within industry, can lead to significant alterations in the overall energy intensity for industry. The change in production structure is also associated with the urbanisation process.

Rising energy needs in the transport sector have been the result of increased demands for personal transport and freight transport. Personal mobility is linked closely to the level of personal income, though the relationship may be influenced by such factors as population density, population distribution and transport costs. The level of freight movement in a country is closely linked to the level of economy activity, in particular industrial production. If more goods are produced, more transportation is generally needed.

In addition, the rapid rise of transport energy use could also be attributed to the substitution of fuel propelled vehicles for non-fuel propelled ones (that is, on foot, by animals and bicycles), the penetration of the more energy intensive transport modes, private cars, in the higher income developing countries, and the rapid expansion of air transport.

For many individual countries, the long term trends show a similar relation, but there are significant variations between average rates of growth in different periods of time for energy consumption and gross domestic production, GDP **[Figure 4.9]**. The characteristics growth in the energy-output ratio during the industrialisation (with the well-known result that the energy intensity increased as the infrastructure and heavy industry developed, going through a peak and then a steady decline) suggests that the energy coefficient (equal to the energy growth rate divided by the economic growth rate) is greater than unity during the later stages of development.

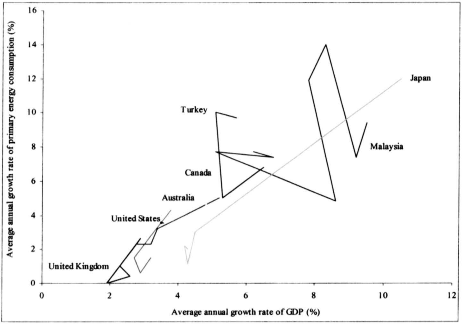


Figure 4.9. *Comparison of average annual growth rate of GDP and associated energy consumption growth of various countries.*

It is thus instructive to use a modified form of **Figure 4.8** to compare the behavior of the energy-output ratio for world regions at different stages of development **[Figure 4.10]**. The peak which occurs at lower energy intensity for late comers in the industrial process such as Japan as compared to their predecessors, e.g. UK and US, indicating early adoption of innovations and modern, more energy efficient industrial processes and technologies.

The energy coefficient of unity reflects a balance between a relative fast growth in energy demand for sectors such as transport and a relatively slow growth in energy for industry, where efficiency improvements continued to reduce the energy-output ratio.

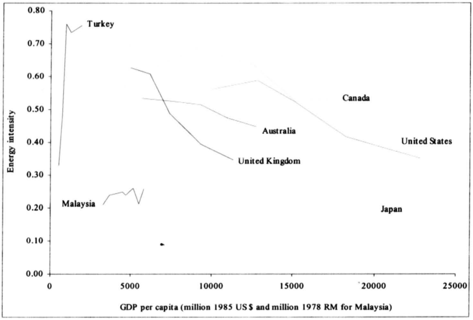


Figure 4.10. *Modified form of **Figure 4.8** to compare energy intensity of various countries.*

Historical evidence suggests that the energy coefficient for developing countries had been larger than unity due partly to industrialisation and partly to the substitution of commercial energy (fossil fuels and electricity) for non-commercial energy (wood fuel and farm waste). The coefficient then stabilizes near to unity for a period and then become less than unity in a mature industrial country.

Thus, the energy-output ratio, on average, generally increased during industrialisation as energy intensive industries were more rapidly developed than other parts of the economy, but later declined as the industrial mix became more stable and there were continuing improvements in the efficiency of the use of energy *(Eden et al,, 1982)*.

4.2. Emissions of Sulphur Oxides

4.2.1. Preliminary Analysis - comparison between two sets of data

As outlined in the methodology discussed in Chapter 3, t-Test was performed to examine if the differences between the two sets of data obtained are statistically significant. Results of the analysis is presented in **Table 4.1**.

Table 4.1 T-Test: Significance of differences in primary energy consumption as obtained from the two data sources.

Group Statistics

	Data source	N	Mean	Std. Deviation	Std. Error Mean
Energy consumption	DOE	98	2185.969	3191.029112	322.3426
	Calculated	432	716.7038	1397.865280	67.254825

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Energy consump	Equal variance assumed	122.951	.000	7.054	528	.000	469.2656	08.29568	060.076	878.456
	Equal variance not assumed			4.462	105.584	.000	469.2656	29.28403	16.3983	122.133

A low significance value for the t-test (typically less than 0.05) indicates that there is a significant difference between the two groups of data, i.e., from the Department of Environment and, as calculated from the Ministry of Energy, Telecommunications and Posts. As such, subsequent analyses were conducted separately for the two sets of data obtained for the study.

4.2.2. Analysis of Fuel Type and Sectoral Contribution to the Consumption of Primary Energy and Associated SO_x

(i) Primary Energy Consumption for various types of fuel:

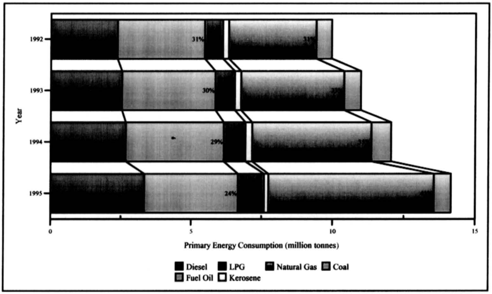


Figure 4.11 Primary energy consumption of various fuel types as per the data set from the Department of Environment.

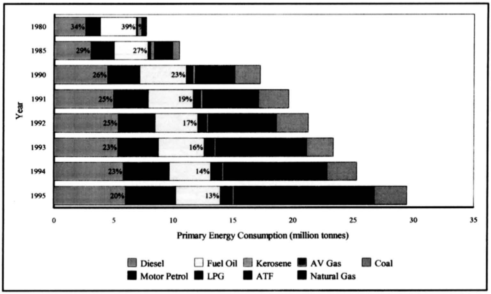


Figure 4.12 Primary energy consumption of various fuel types as per calculated from the data set obtained from the Ministry.

Despite the differences between the two sets of data, both **Figures 4.11 - 4.12** indicated that major primary energy supply in Malaysia are natural gas, diesel and fuel oil.

(ii) Primary Energy Consumption by various economical sectors:

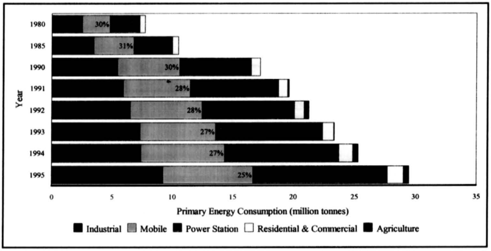


Figure 4.13 Primary energy consumption for various economic sectors as calculated from the data set obtained from the Ministry.

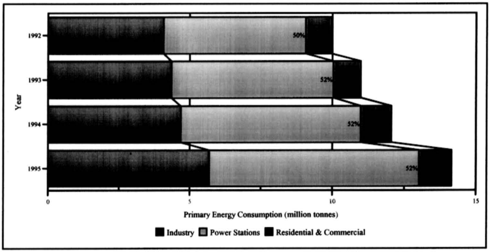


Figure 4.14 Sectoral primary energy consumption as published by the Department of Environment.

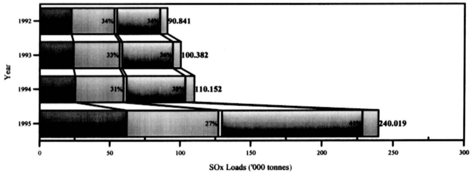
Figure 4.13 shows that industrial sector and power stations consumed the most significant portions of primary energy in Malaysia. The supply of electric energy must increase significantly in the future to meet the energy requirements of a greater population, an expanding economy, and as a substitute for dwindling reserves of gas and oil *(Gilleland, 1978)*.

Although **Figure 4.14** as per data obtained from DOE did not reflect consumption made by the mobile or transportation sector, it had also identified these two sectors as the prime energy consumer.

(iii) Emissions of SO_x from various types of fuel:

Analysis of both sets of data clearly indicates that the level of SO_x has been increasing throughout the years **[Figure 4.15 and 4.16]**. This is in line with the ambient SO_x monitoring reported for the Klang Valley by Lodhi *et. al.* (1997).

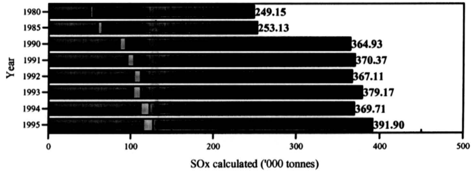
However, the SO_x load as published by DOE seemed unacceptable as, not only the amount of emissions had increased tremendously in 1995, but the data had also identified natural gas to be the prime contributor to the total emission load. Almost all the literature reviewed confirmed that natural gas is the cleanest option of fossil fuel in regard to its environmental impacts, including the emissions of SO_x *(e.g. Chin, 1996)*.



	1992	1993	1994	1995
Diesel	22.5	24.08	25.37	62.11
Fuel Oil	30.56	32.71	34.37	65.07
LPG	0.011	0.012	0.012	0.009
Kerosene	1.8	1.83	2.06	2.59
Natural Gas	30.74	36.14	41.78	98.88
Coal	5.23	5.61	6.56	11.36

Figure 4.15 *SO_x loads due to the consumption of various fuel types (data source: DOE)*

The calculated SO_x from data available from the Ministry of Energy, Telecommunications and Posts were, on the other hand, in line with the findings reported by Chin (1996) where fuel oil and diesel were identified to be the major culprit in polluting the environment in terms of the total SO_x load resulting from the consumption of energy. **[Figure 4.16]**



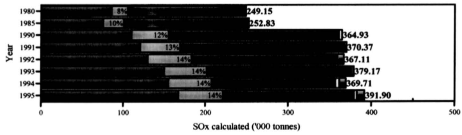
	1980	1985	1990	1991	1992	1993	1994	1995
Diesel	50.47	59.57	86.24	95.74	103.61	102.95	112.00	115.47
Motor Petı	3.43	5.44	7.55	8.16	8.66	9.55	10.78	11.84
Fuel Oil	193.36	181.58	250.00	241.75	228.97	245.01	222.91	238.22
Kerosene	1.08	0.95	0.62	0.55	0.49	0.46	0.47	0.54
Coal	0.82	5.60	20.52	24.17	25.37	21.21	23.56	25.82

Figure 4.16 SO_x calculated as per the consumption of various fuel types published by the Ministry of Energy, Telecommunications and Posts.

Although total emissions of SO_x calculated were relatively higher than the data obtained from DOE, the range was however considered possible as per the SO_x emissions reported by Kato (1996) i.e. 193 ktonne in 1975, 272 ktonne (1980) and 263 ktonne (1987).

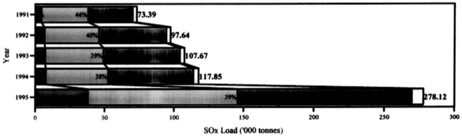
(iv) Emissions of SO_x from various types of fuel:

Despite the differences noted in terms of total SO_x emitted for a specific year from respective fuel types, both sets of data suggested that power stations together with the industrial sector contributed most to the total emissions of SO_x **[Figure 4.17 and 4.18]** in Malaysia throughout the years. The two sectors had also been identified to be the major consumer of primary energy.



	1980	1985	1990	1991	1992	1993	1994	1995
Industrial	86.17	75.73	110.34	121.03	130.07	150.00	155.17	167.43
Mobile	19.47	24.97	44.96	48.49	53.22	51.72	52.56	54.00
Power Statio	142.50	151.26	206.01	196.86	174.57	174.28	149.30	157.82
Res/Comm	1.01	0.87	3.62	1.29	1.53	2.43	4.62	3.55
Agriculture	0.00	0.00	0.00	2.70	7.72	0.73	8.07	9.09

Figure 4.17 *SO_x calculated for various economical sectors as per the consumption of various fuel types published by the Ministry of Energy, Telecommunications and Posts.*



	1991	1992	1993	1994	1995
Mobile	4.4	6.8	7.2	7.7	38.1
Industry	33.78	39.29	42.06	45.1	107.78
Power Station	32	48.44	55.08	61.28	123.92
Res/Comm	3.21	3.11	3.33	3.77	8.32

Figure 4.18 *SO_x loads of various primary energy consuming sectors (data source: DOE).*

4.2.3. Linear Regressions of SO_x Emissions and Primary Energy Consumption

(I) Emissions of SO_x and Overall Primary Energy Consumption:

Both sets of data as pointed out in their respective regression analysis agreed that emissions of SO_x would increase if the amount of primary energy consumed had increased **[Figure 4.19 - 4.20]**:

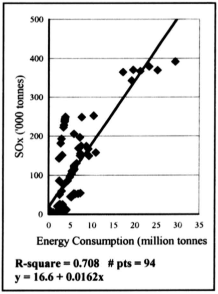


Figure 4.19

Regression analysis of SO_x calculated and their respective values of primary energy consumed in Malaysia.

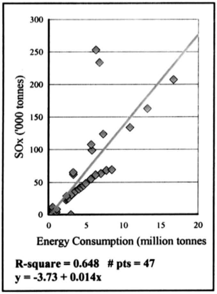


Figure 4.20

Regression analysis of SO_x and their respective primary energy consumption values as published by DOE of Malaysia.

(ii) Emissions of SO_x and Primary Energy Consumption as per Fuel Type:

Regression was also conducted for the set values available for both SO_x and its associated fuel type consumption. It was noted that data from DOE presented a higher value of R^2 (= 0.95) compared to as when overall values of both SO_x and energy consumption were taken as per earlier discussion (R^2 = 0.648).

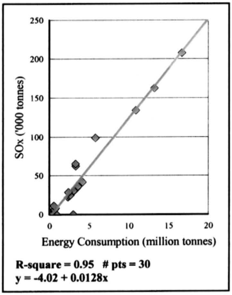


Figure 4.21

Higher value of R^2 when only the contributions of SO_x by various fuel types were analysed. [Data source: DOE]

This was very different from that of the regression analysis performed on the calculated SO_x when only respective values for each fuel types were taken into account. The R^2 value was only higher if nonlinear regression was considered, i.e. $R^2 = 0.782$ for $y = 0.000304x^{1.47}$. This was due to the variance of sulphur contents and emission factors taken during the calculation of SO_x. **[Figure 4.22]**

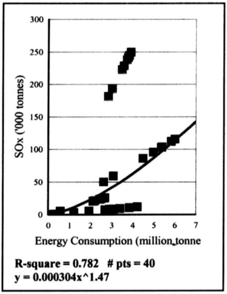


Figure 4.22

Power Regression with a higher value of R^2 when only the contributions of SO_x as calculated for various fuel types were analysed.

(iii) Sectoral Contributions of SO_x and Their Primary Energy Consumption:

Both data sets demonstrated high values of R^2 when only sectoral contribution was considered. **[Figure 4.23 - 4.24]**

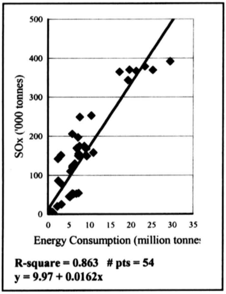


Figure 4.23

Linear Regression with the highest value of R^2 when only sectoral contributions were considered.

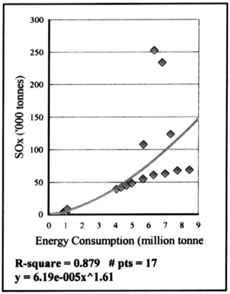


Figure 4.24

Exponential Regression of sectoral SO_x contributions for data available from Department of Environment.

4.2.4. Analysis of Variance (ANOVA) for the Emissions of SO_x

Since the regression analyses confirmed that consumption of primary energy will contribute significantly to the emissions of SO_x, further examination was to identify main contributor(s) of specific fuel type(s) and/or economical sector(s).

(I) Significant Fuel Type Contributor(s) of SO_x:

Analysis of Variance (ANOVA) was used for the purpose where relevant data on the emissions of SO_x for each fuel types were entered into the SPSS software for the computation of mean SO_x and subsequent *post-hoc tests* in order to assess if there is any significant variance between the various input of independent variable.

Plots derived from the analysis of both sets of data, i.e., from the Department of Environment and, as calculated from the Ministry of Energy, Telecommunications and Posts are shown in **Figure 4.25 - 4.26.**

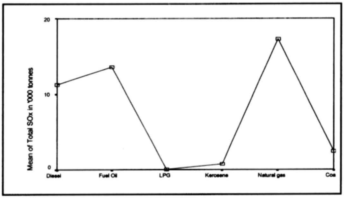


Figure 4.25 Mean plot of SO_x for each fuel type as per data obtained from the Department of Environment.

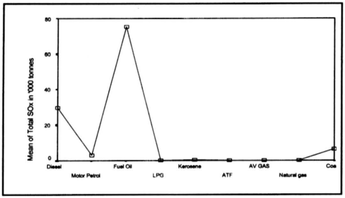


Figure 4.26 *Mean plot of SO_x for each fuel type as per calculated from data obtained from the Ministry of Energy, Telecommunications and Posts.*

Post-hoc tests had then identified that fuel oil and diesel are significantly higher (i.e. with a positive values of the *mean difference*) than other fuel types in their contribution to SO_x in both cases **[Appendix C]**. However, as discussed earlier, SO_x contributed by natural gas appeared to be the highest as per data obtained from DOE.

(ii) Significant Sectoral Contributor(s) of SO_x:

Similar process of ANOVA was repeated for the analysis on significant economical sector in the contribution of SO_x emissions. Results of the set data from DOE could only identified the *residential and commercial* sector to be significantly lower than the other three sectors of *industrial, transport and power stations* in regard to their respective SO_x contributions. **[Figure 4.27 and Appendix D]**

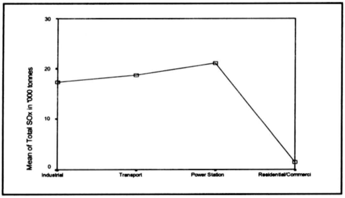


Figure 4.27 *Mean plot of the sectoral SO_x as per data obtained from the Department of Environment.*

The calculated data set of SO_x from the Ministry of Energy, Telecommunications and Posts had, on the other hand, confirmed the significant role of power stations and industrial sector in this regard. It was however noted that the transportation sector was not significantly different from the other sectors except that of the power stations in their respective SO_x emissions **[Figure 4.28 and Appendix D]**.

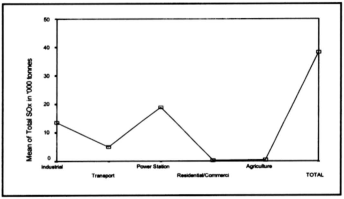
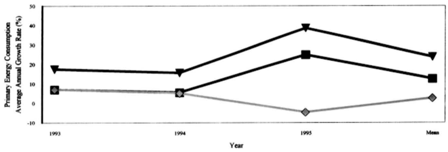


Figure 4.28 *Mean plot of sectoral SO_x as calculated from data obtained from the Ministry of Energy, Telecommunications and Posts.*

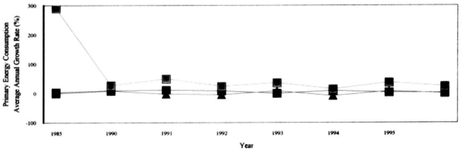
4.2.5. Average Annual Growth Rate of Significant Contributors of SO_x

The following analyses on the average annual growth rate of significant contributing independent variables in the emissions of SO_x, as identified in earlier analyses, aim to assess their respective potential loads of SO_x should there be no critical policy or control measures put in place by the government to limit their further emissions of SO_x. **[Figures 4.29 - 4.32]**



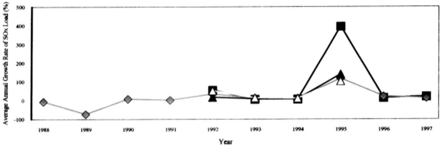
	1993	1994	1995	Mean
Diesel	7.01	5.45	25.01	12.49
Fuel Oil	7.03	5.06	-4.59	2.50
LPG	6.98	11.16	20.73	12.96
Kerosene	7.14	7.11	-36.93	-7.56
Natural Gas	17.52	15.62	38.56	23.90
Coal	7.27	16.95	-13.33	3.63

Figure 4.29 *Average annual growth rate of significant fuel types for the contribution of SO_x as per data obtained from the Department of Environment.*



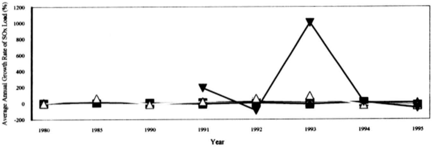
	1985	1990	1991	1992	1993	1994	1995	
Diesel	3.49	9.10	11.02	8.22	-0.64	8.79	3.11	2.15
Motor Petrol	11.71	7.79	8.07	6.09	10.22	12.90	9.88	3.33
Fuel Oil	-1.22	7.54	-3.30	-5.29	7.01	-9.02	6.87	0.13
LPG	18.56	27.80	11.14	20.17	16.14	9.39	8.32	5.58
Kerosene	-2.34	-6.90	-11.33	-11.11	-6.88	2.01	16.45	-1.00
ATF	10.88	12.54	9.55	10.76	14.44	11.58	19.01	4.44
AV Gas	0.00	10.00	-33.33	0.00	50.00	66.67	-60.00	1.67
Natural Gas	290.00	26.57	49.06	23.35	35.48	14.22	36.94	23.78
Coal	116.60	53.26	17.80	4.99	-16.40	11.09	9.59	9.85
AAGR	49.74	16.41	6.52	6.35	12.15	14.18	5.57	5.55

Figure 4.30 *Average annual growth rate of significant fuel types for the contribution of SO_x as per calculated based on data obtained from the Ministry of Energy, Telecommunications and Posts.*



	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Mobile					54.55	5.88	6.94	394.81	13.65	20.32
Stationary	-7.47	-72.97	7.55	1.43	32.69	10.85	9.78	116.72	21.41	12.55
Industry					16.31	7.05	7.23	138.98		
Power Station					51.38	13.71	11.26	102.22		
Res/Comm					-3.12	7.07	13.21	120.69		

Figure 4.31 *Average annual growth rate of significant contributing sectors for the emissions of SO_x as per data obtained from the Department of Environment.*



	1980	1985	1990	1991	1992	1993	1994	1995
Industrial	-2.42	9.14	1.94	7.47	15.33	3.44	7.90	-25.65
Mobile	5.65	16.01	1.57	9.75	-2.80	1.61	2.75	-19.12
Power Station	1.53	7.24	-0.89	-11.33	-0.17	-14.33	5.71	6.97
Residential/Comm	-2.80	63.55	-12.86	18.55	58.78	89.82	-23.05	-33.44
Agriculture				186.23	-90.50	1000.53	12.70	-61.08

Figure 4.32 *Average annual growth rate of significant contributing sectors for the emissions of SO_x as per calculated based on data obtained from Ministry of Energy, Telecommunications and Posts.*

It was noted that the average annual growth rate of the consumptions of fuel oil and diesel had been maintained at a certain range and were slightly slower as compared to the growth rate of natural gas. In other words, should the information regarding the cleanliness of natural gas valid, more focus should be targeted in the aspect of SO_x contributed by respective sectoral users rather than the potential contribution of fuel oil and diesel to the emissions of SO_x .

This is based on the relatively higher rate of average annual growth rate trends as reported by both data sources in regard to the development of sectoral contributions of SO_x by the industries, power stations as well as the mobile/transportation sector of Malaysia.

In addition, by controlling the energy consumptions and their respective SO_x emissions resulted from these sectors, significant reduction could be foreseen as they are also the main consumer for fuel oil and diesel **[Figure 4.33 - 4.34]**. Of these sectors, the industrial sector seemed to consume a significant level of fuel oil and/or diesel as compared to the power stations where the priority had since been shifted to natural gas in the recent years. **[Figure 4.35 - 4.36]**

Similar observation was noted in a study by Von Hippel (1997) where it was explained as that, the industrial sector fraction of fuels demand is greater in the less developed countries, i.e. China and North Korea, than in Japan and South Korea.

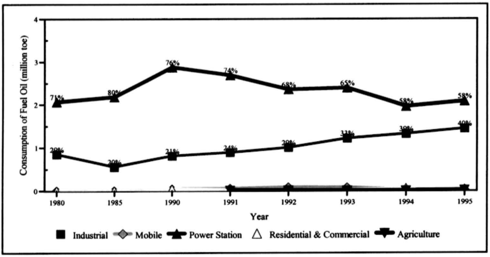


Figure 4.33 *Sectoral breakdown of the consumption of fuel oil. [Data source: Ministry of Energy, Telecommunications and Posts]*

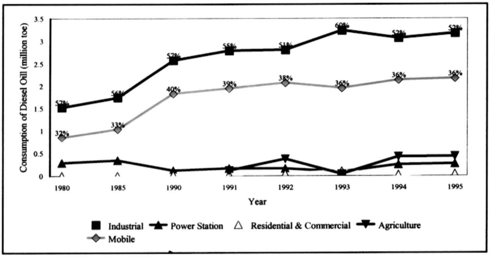


Figure 4.34 *Sectoral breakdown of the consumption of diesel oil.*
[Data source: Ministry of Energy, Telecommunications and Posts]

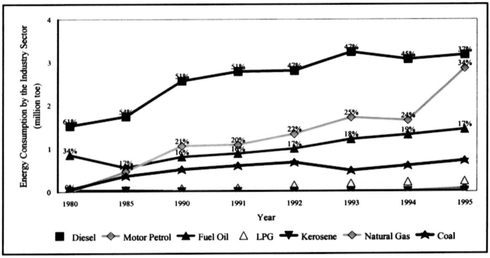


Figure 4.35 *Analysis of the types of fuel consumed by the industrial sector of Malaysia.*
[Data source: Ministry of Energy, Telecommunications and Posts]

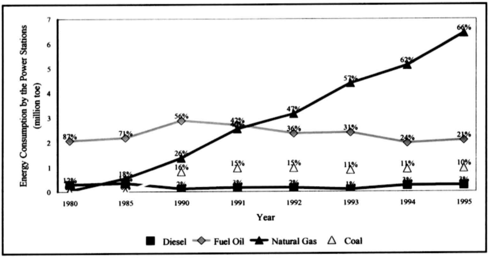


Figure 4.36 *Analysis of the types of fuel consumed by power stations in Malaysia.*
[Data source: Ministry of Energy, Telecommunications and Posts]