LONG - TERM ENERGY SUPPLY PLAN

(Thailand Energy Master Plan)

submitted to

NATIONAL ENERGY ADMINISTRATION

Ministry of Science, Technology and Energy

KINGDOM OF THAILAND

by

OSAMU KUMAKURA

Japan International Cooperation Agency

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PREFACE

This report contains all papers which I have written for the Energy Master Plan Project in my stay at Energy Policy and Planning Division, National Energy Administration, as a JICA (Japan International Cooperation Agency) expert, from December 1985 to June 1987.

Part I is the latest outcome of our works. An draft on the long-term energy supply plan is developed using the results of runs of the model. Following the methodology in the EMP reports, I intended to utilize the results as much as possible in this report. However, because the validation of the model is not yet complete, much more will be said by the further improvement of the model.

The purpose of Part I is only to present informations to be refered in developing the energy supply plan by NEA. And, the views presented here are the anther's personal ones, and not necessarily of NEA.

Part II presents some works relating to the proper works of EMP project. Chapter 1 and 2 deals with the demand analysis for the two principal energy consuming sectors, i.e. transportation sector and household-tertiary sector. The mechanisms of determining energy consumption are analysed by the method of econometrics. The results may be useful for the improvement of the demand block of EMP Model, or for the compilation of the input data and the interpretation of the results on the demand side.

In Chapter 3, pricing mechanisms of crude oil and petroleum products in the international market are analysed by simple econometric method. This analysis is not an accomplished one, and has many points to be improved.

In Part III, how to utilize the full capacity of the model is discussed. At first, the capabilities and limitations of the model are presented in details. It is essential to know them for the fuel utilization of the model. Next, some personal opinions about the organization of works are presented.

In Appendix I, some technical papers about the methodologies of compiling the input data and of analizing the results are recorded. And in Appendix II, the terms of reference and related documents are recorded.

This report is accomplished with the supports by many people. Especially, I would like to express my appreciation to Mr. Mohar Singh Monga, Director of Energy Policy and Planning Division, Ms. Dunchird Kulphanich, Chief of Energy Master Plan Project, and the staffs, Mr. Supot Tadyu, Mr. Manoch Jenakom, Ms. Kanda Taipanich, Mr. Suthat Chobchuen, Mr. Trirong Santimetrikul, Ms. Saipin Cintakulchai, Mr. Thaveesakdi Tooppanom, Mr. Kittipong Rattanapisutikul, Mr. Amorn Na Thaland, Ms. Vannee Khummongkol, Ms. Prapapan Peampratom and Ms. Jitra Suriyavong. And I like to express my special thanks to my secretary, Ms. Srisamorn Lukitcharoenkul.

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PART 1

LONG-TERM ENERGY SUPPLY PLAN

I. Introduction

1. Background of Long-Term Energy Supply Plan

1). The Present Situation on Energy

Energy demands increase still with a strong correlation which economic development in this country. Although the growth rate was suppressed by the two oil shocks, total energy demand has increased at 3.6% per year from 1975 to 1985 compared with the GDP growth rate of 6.4% per year in the same period, which brings GDP elasticity of total energy demand 0.56 (Table I-1). For the total of the modern energy, the growth rate is 5.0%, and the GDP elasticity is 0.70.

Table I-1 : End-Use Energy Consumption

(KTOE)

	1975	1980	1985	Growth Rate 1975-1985
Electricity	638	1,120	1,707	10.3%
Petroleum Products	6,527	7,912	9,388	3.7%
Coal & Lignite	29	114	422	30.7%
Natural Gas	-	-	181	-
Sub Total	7,192	9,146	11,698	5.0%
Traditional Energy	6,390	6,579	7,734	1.9%
Total	13,584	15,725	19,432	3.6%
GDP	203,514	292,852	378,756	6.4%

Source : NEA

Table I-2 : Primary Energy Demand

(KTOE)

	1975	1980	1985	Growth Rate 1975-1985
Hydro-Electricity	767	347	878	1.4%
Petroleum Products	7,791	21,895	10,154	2.6%
Coal & lignite	149	447	1,587	26.7%
Natural Gas	-	-	3,496	-
Sub Total	8,707	12,709	16,115	6.3%
Traditional Energy	9,718	10,840	11,603	1.7%
Total	18,431	23,549	27,718	4.2%

Demand = Domestic Production + Import - Export

Source : NEA

On the primary energy bases, the growth rates of the demand are higher than on the end-use energy bases. The growth rate of the total energy is 4.2% per year and that of the modern energy is 6.3%.

The energy demands will be required to increase both for rising people's standard of living and for promoting economic development. Actually the major factors which increase the demands are such as rural electrification, diffusion of electric appliances and equipments, industrial development with modernized technology, development of transportation etc. In spite of some factors which decrease the GDP elasticity of energy demand, such as improving efficiency or conservation of energy, structural changes of industry (industrial or transportation sector) into more energy efficient one and etc., it is appropriatoty forefeen that the trend in the past of energy demand will continue without large modifications (declining the trend) in the near future.

On the supply side, the supplies of indigenous energy, such as natural gas, crude oil and lignite started to increase in the recent years. Especially natural gas supply will be in the matured stage in the immediate future and contribute largely to increase domestic supply of energy. And consumption of lignite will increase also gradually as it will become more economic in the long-run.

By the increase of indigenous supply of energy the dependency on import has rapidly declined recently (Table I-3). And also by the recent decline of import prices of energy, the burden on foreign exchange by importing energy has been lightened, as shown in Table I-4. However, decreasing import of energy will be still a salient policy issue, because, import price of energy (especially of crude oil and petroleum products) will increase at relatively high rate, reflecting the market which is forecasted to become tight in the long-run.

Table I-3 : Imports of Energy

(KTOE)

	1975	1980	1985
Crude Oil	7,156	7,913	6,751
Petroleum Products	711	2,707	2,357
Coal	4	43	189
Electricity	14	63	62
Traditional Energy	1	4	8
Total	7,886	10,730	9,367
Share in Total Demand 1)	90.6	84.4	58.1
2)	42.8	45.6	33.8

1) Share in total demand of modern energy on primary energy bases

2) Share in total demand of energy on primary energy bases

Table I-4 : Import of Energy

(Millions of Bahts)

	Mineral fuel and lubicant	(% of the total)	Total
1980	58,733	(31.1)	188,686
1981	65,100	(30.0)	216,746
1982	60,765	(30.9)	196,616
1983	57,065	(24.1)	236,609
1984	57,353	(23.4)	245,155
1985	56,718	(22.6)	251.169
1986 1)	27,768	(13.9)	200,356

1) : up to October 1986

Source : Bank of Thailand

More details will be discussed for types of energy. The total electricity demand increased at 10% per year and increase by more than 160% from 1975 to 1985. The demands increased both in the industial and the household-tertiary sectors. However, the per-capita consumption of electricity in household remains still low, and not-electrified population remains still large. The promotion of electricity consumption by household is one of the principal policy objectives.

The consumption of petroleum products increased at 3.7% per year in the same period. The largest part of it is consumed in the transportation sector. The consumption of diesel oil increased at 5% per year mainly by this sector. On the other hand, the consumption of gasoline was stagnant in the recent several years. The consumption of fuel oil has decreased because of the substitution to the other energy sources (natural gas, coal, lignite and electricity). These structural changes of consumption and some discrepancy of market mechanism are related with the pricing policy which has brought distortions from their supply costs into the prices. The pricing policy for petroleum products which aims to make the market more efficient by setting the prices close to the international prices, along with the investment policy on oil refinery to reconcile with it on the supply side, will remain valid in the future.

The consumption of natural gas which started in 1981 has increased rapidly mainly by the electricity sector. It attained more than 10% of the total supply of energy in 1985, and arround 1996 when the supply will reach the peak it will attain about

20%. Consequently for the present, it is urgently required to get the clear prospects on supply and utilization of natural gas in the next decade, because the investments related to natural gas must be implemented on the long-term prospects.

The consumptions of lignite and coal have increased recently. These two fuels, at the present, do not have substantial cost advantages to the other fuels. It is necessary to appreciate these fuels in long-term viewpoint as they will become economic.

The traditional energy is still the largest source in the rural sector. Although it will be substituted gradually by the modern energy, it still remain the principal energy source in this sector. The problems concerning supply and consumption of the traditional energy, such as depletion of wood resources and promotion of utilization of agricultural wastes, will become to be treated by economic rational, same as for the modern energy, as the rural sector becomes involved in commercial market.

2). Policy Issues

Long-term policy issues concerning energy supply in this country can be listed as follows, according to the policy objectives derived from different viewpoints such as efficient supply and consumption system (both in micro-economic and macro-economic points of view) and other points of view (for example, equity and welfare for the people).

- Optimum allocation of investments in the energy sector

  This can be implemented by some different criterions such as minimizing total investment costs for energy supply in this country and maximization of economic growth rate. Allocation of investments in the electricity sector among types of unit and in oil refinery sector concerning its cofigulation are the main issues.

- Pricing of energy

  To realize efficiency in the international environment through market mechanism, the prices should be set close to the international prices. However, consideration on equity or welfare must be reserved for example for rural electrification or generally promotion of energy consumption relating to the people's welfare.

- Promoting indigenous energy supplies

  This has positive affects on the economic development by decreasing the burden of foreign exchange.

- Rural electrification, promoting or subsidizing infant industries and other issues such as protection of environment and energy security of this country, etc.

These issues, although not discussed here explicitly, should be also considered in parallel with the issues above.

- Other issues specific to the demand side such as energy conservation.
- Macro-economic and industrial policies affecting energy consumption.

2. Methodology and Assumptions

1). Methodology

EMP Model is an optimization model which determines the optimal supply structure and allocation of investments in the energy supply sectors, in the viewpoint of minimization of total cost of energy supply in this country.

Pricipal exogenous factors are end-use energy demands, import prices and extraction cost of energy and constraints on supply capacities in the energy sectors. With these variables given from outside, the model determines optimal solutions by linear programing (for the period from 1986 to 2001).

The end-use energy demands are forecasted by (linkage) equations and energy intensities by sector (and by type of energy in some cases). The equations determine output or income levels, or other factors by sector, which determine energy consumptions based on GDP or GDP components. And these factors and the energy intensities determine the energy demands by sector (by type of energy in some cases), which are inputted in the model.

The constraints on supply capacities are set based on informations on the actual situations, and forecasts and capacity expansion plans prepared by concerned agents.

2). Assumptions

The values for the exogenous factors for Base Case are set as the most probable ones, taking into consideration the consistency with the targets by the 6th plan. Consequently, the results can be considered as the recommended plans corresponding the most probable future.

However, as the assumptions are not free from uncertainties, the runs by alternative scenarios should be conducted to analyse how the results change if some of the assumptions change.

The assumptions for Base Case are as follows:

GDP

The real GDP growth rate is assumed to be 4.9% per year from 1986 to 1991, 4.5% from 1991 to 1996 and 4.2% from 1996 to 2001.

Energy Prices (shown in Table 1-5)

The import price of crude oil (current prices) is assumed to increase to 21$/bbl in 1991, 24$/bbl in 1996 and 28$/bbl in 2001. The import prices of petroleum products increase at the same rate as crude oil. The import price of coal will increase from 43.6$/ton in 1986 to 59.6$/ton in 2001 at 2.1% per year. The mine-mouth price of lignite increases from 475 Baht/Ton in 1986 to 649 Baht/Ton in 2001 at the same growth rate as import coal. The price of domestic crude will increase at the same growth rate as import crude, and the well-head price of natural gas will increase according to the existing pricing formula.

Table I-5 : Assumptions on Energy Prices

	Unit	1986	1991	1996	2001
Import					
Crude Average	US$/BBL	14.44	21.05	24.40	28.29
LPG	US$/BBL	17.23	25.11	29.11	33.74
Premium Gasoline	US$/BBL	20.88	30.44	35.29	40.91
Regular Gasoline	US$/BBL	17.93	26.14	30.30	35.13
Kerosene	US$/BBL	17.28	25.18	29.20	33.85
Jet Fuel	US$/BBL	23.73	34.60	40.11	46.50
High Speed Diesel	US$/BBL	18.59	27.10	31.41	36.41
Low Speed Diesel	US$/BBL	18.19	26.51	30.73	35.62
Fuel Oil	US$/BBL	10.34	20.10	23.30	27.01
Coal	US$/TON	43.63	48.41	53.71	59.59
Domestic					
Phet Crude	US$/BBL	11.50	16.76	19.43	22.53
Natural Gas (1)	US$/MBTU	2.23	1.99	2.08	2.26
Lignite (2)	BAHT/TON	475.00	527.01	584.72	648.75

(1) Well-head price at Erawan

(2) For electricity generation

In short, it is assumed that the prices of coal and lignite will become relatively cheap compared with the prices of oil and natural gas, because the markets for the latters will become tight in the long-run.

Constraints set on the capacities of extraction of domestic energy and conversion are shown in Table I-6. For natural gas, crude oil and lignite, constraints can be considered as economically recoverable capacities. Constraint on the oil refinery sector is set only on the capacity of crude units, and is fixed at the levels of TORC's expansion plan Phase 2 in 1991 and installation of a new unit of 65 Kbbl/day after 1996. For the electricity sector, constraints are set based on EGAT actual plans.

Tablo I-6 : Maximum capacity constraints on domestic energy supply

	1986	1991	1996	2001
Natural Gas (MMSCFD)	350	720	950	860
Phet Crude (KBD)	20.8	27.1	7.9	-
Lignite (KTON)				
Electricity	5,271	8,952	no constraint	no constraint
Industry	723	1,001	3,085	3,539
Oil Refinery (KBD)				
Crude Unit	183	201.5	266.5	266.5
Electricity (MW)				
Thermal				
Coal	-	-	600	2,550
Combined - Cycle	720	720	1,320	1,320
Dendro	-	-	395	395
Lignite	885	1,485	1,800	1,800
Oil-Gas-Coal	-		-	1,200
Oil-Gas	no constraint	no constraint	no constraint	no constraint
Gas Turbine & Diesel	60.1	60.1	37.1	-
Hydro				
Large	2,062	2,062	2,822	3,192
Medium	185	185	231	231
Micro-Mini	22	67	98	128

II. Enenrgy Demand and Supply : Outlines

1. Prospects on Long-Term Supply-Demand Structure

Principal indicaters by Base Case concerning end-use energy demands are shown in Table II-1. Total demand of end-use energy is forecasted to increase at 3.3% per year from 1986 to 2001. And the GDP elasticity of demand is 0.73 which is slightly larger than one in the past one decade.

Table II-1 : End-Use Energy Consumption

(KTOE)

	1986	1991	1996	2001	Average Growth Rate 1986-1991	1991-1996	1996-2001	1986-2001
Electricity	1,849	2,672	3,503	4,536	7.6	5.6	5.3	6.2
Petroleum Products	10,434	13,433	16,336	19,625	5.2	4.0	3.7	4.3
Coal & Lignite	444	746	1,137	1,606	10.9	8.8	7.2	8.9
Natural Gas	192	369	329	499	13.9	3.1	3.1	6.6
Sub total	12,920	17,220	21,405	26,268	5.9	4.5	4.2	4.8
Traditional Energy	6,592	6,831	6,987	7,120	0.7	0.5	0.4	0.5
Total	19,521	24,051	28,392	33,388	4.3	3.4	3.4	3.3

The figures for 1986 are the results of runs, and not necessarily equal to the actual values throughout the report.

As the demands for the traditional energy is forecasted to increase at 0.5% per year in the same period, the increase of demand is met largely by the modern energy. The growth rate of the demand for modern energy is 4.8% per year which is slightly lower than the past ten years growth rate, and corresponding GDP elasticity is 1.07.

Consequently, the share of modern energy in the total demand will increase from 66% to 79% from 1986 to 2001. And, although their share in the total modern energy will decline, petroleum products will remain to occupy the largest part (75% in 2001). The demand for electricity is the second largest, and will continue to increase the share. The end-use demands for coal, lignite and natural gas will still remain small, although the growth rates will be high.

Turning to the supply side, the forecasts of primary energy supply are shown in Table II-2. Total supply of primary energy (excluding exports) is forecasted to increase at 3.9% per year in the period. And that of modern energy will increase at 5.4% in the period, which is higher than the growth rate of the end-use demand for modern energy because of the conversion especially in the electricity sector. In terms of primary energy, supply of coal, lignite and natural gas will occupy larger shares and show higher growth rates than in terms of end-use energy, because their consumption by the conversion sectors especially by the electricity sector will increase. Accordingly hydroelectricity shows lower growth rates.

Table II-2 : Primary Energy Demand

(KTOE)

	1986	1991	1996	2001	Average Growth Rate 1986-1991	1991-1996	1996-2001	1986-2001
*)**) Electricity	1,155	1,309	1,726	1,967	2.5	5.7	2.6	3.6
Petroleum Products	10,825	12,983	15,790	19,037	3.7	4.0	3.8	3.8
Coal & Lignite	1,762	2,976	4,631	8,360	11.1	7.9	12.5	10.9
Natural Gas Condensate	3,358	6,863	8,397	8,255	15.4	4.1	-0.3	6.2
Sub total	17,100	24,131	30,544	37,619	7.1	4.8	1.4	5.4
**) Traditional Energy	10,964	11,389	11,745	11,978	0.8	0.6	0.4	0.6
Total	28,064	35,520	42,289	49,597	4.8	3.6	3.2	3.9
Export Condensate	325	435	342	332	6.0	-4.7	-0.6	0.1

Demand = Domestic Production + Import - Export

*) Expressed in Toe converted using generation efficiency

**) Bases of calculation changed from Table I-1 and I-3.

The imports of energy are forecasted as shown in Table II-3. The shares of import in the total supply of energy are forecasted to decline until 1991, and increase after that. The share of import in the total modern energy will increase to 64% in 2001, from 59% in 1986. The supply increases of the indigenous energy will have substantial effects in substuting import in short-run, however the effects will be gradually cancelled by the increase of the domestic demand. The imports of energy especially of crude oil and petroleum products will remain the important factors which affect the economic growth rate.

Table II-3 : Imports of Energy

(KTOE)

	1986	1991	1996	2001
Crude Oil	7,021	7,912	11,490	11,463
Petroleum Prod.	2,783	4,297	4,300	7,574
Coal	182	310	1,418	4,340
Electricity	76	69	65	61
Total	10,062	12,588	17,273	23,938
Share in Total Demand 1)	58.8	52.2	56.6	63.6
2)	35.9	35.4	40.8	48.3

1) : Share in total demand of modern energy on primary energy bases

2) : Share in total demand of energy on primary energy bases

2. Energy Demand by Sector

End-use energy demands by sector are forecasted as in Table II-4, and their compositions by types of energy are shown in Table II-5 - II-8.

Table II-4 : End-Use Energy Demand by Sector

(KTOE)

	1986	1991	1996	2001	Average Growth Rate 1986-1991	1991-1996	1996-2001	1986-2001
Agri.&Fish.	1,152	1,393	1,582	1,783	3.9	2.6	2.4	3.0
Industry	5,361	6,838	8,185	9,804	5.0	3.7	3.7	4.1
Chemical	223	390	472	572	11.8	3.9	3.9	6.5
Food & Beverage	2,259	2,621	2,955	3,365	3.0	2.4	2.6	2.7
Non-metal	1,203	1,567	1,916	2,332	5.4	4.2	4.0	4.5
Paper	171	244	317	387	7.4	5.4	4.1	5.6
Textile	493	677	858	1,079	6.5	4.9	4.7	5.4
Other Ind.	1,012	1,344	1,667	2,069	5.8	4.4	4.4	4.9
Household & Tertiary	6,320	7,041	7,758	8,486	2.2	2.0	1.8	2.0
Transportation	6,678	8,779	10,867	13,314	5.6	4.4	4.2	4.7
Total	19,512	24,051	28,392	33,388	4.3	3.4	3.3	3.6

1). Transportation Sector

The total energy demand by the transportation sector, which occupies the largest part in the total demand, will continue to increase, and the share will attain 40% in 2001. Looking by types of fuel, the demands for gasoline, which have been stagnant in the recent several years, are forecasted to increase at 4-5% per year. However, the demands for diesel oil will also increase at a similar growth rate. The unbalanced domestic market conditions, where diesel oil is in deficit and gasoline is in surplus, will remain in the future.

In these forecasts, the demands are projected based on the past trends, and any changes in the transportation system are not taken into consideration. The effects on fuel demands by the changes of transportation system (for example, new mass transportation system, reduction of traffic congestion, etc.) are the factors to be analysed in the further studies.

On the other hand, in EMP Model, the fuel demands are determined based on shadow prices which can be considered as supply costs to consummers excluding taxes and retailing costs. In this sence, the demands forecasted can be considered as ones corresponding to hypothetical retail prices which are set close to the international prices. However, because of the limitations of the linear programming model, the demands are not sencitive to prices in the actual runs. We must be careful when we see the relation between the demand forecasts and the prices.

Table II-5 : Energy consumption by Transportation Sector

(KTOE)

	1986	1991	1996	2001	Average Growth Rate 1986 -1991	1991 -1996	1996 -2001	1986 -2001
LPG	291	375	444	539	5.2	3.4	3.9	4.2
Premium Gasoline	659	823	1,003	1,217	4.5	4.0	3.9	4.2
Regular Gasoline	1,009	1,375	1,729	2,143	6.4	4.7	4.4	5.2
HSD	3,372	4,463	5,496	6,680	5.8	4.3	4.0	4.7
LSD	44	57	72	91	5.3	4.6	4.8	5.0
Jet Fuel	1,029	1,331	1,624	2,102	5.3	4.8	4.5	4.9
Fuel Oil	274	354	537	542	5.3	4.3	4.4	4.7
Total	6,679	8,779	10,867	13,315	5.6	4.4	4.1	4.7

2). <u>Industrial Sector</u>

The total end-use energy demand by the industrial sector is forecasted to increase also at a high growth rate. Industrial developments especially in heavy industries such as chemical, non-metal (cement, glass) and others (base metal, metal fabrication) will bring the high growth rate of demand.

Consumption of natural gas and coal will increase in cement industry, and that of lignite also in cement industry and other industries. However, fuel oil and diesel oil will remain to be the main energy source in various industries as sources of motive power and heat. Electricity consumption is forecasted to increase at 5.1% per year from 1986 to 2001. The growth rate of electricity will become higher if self-generation will be substituted by purchased electricity.

As for traditional energy, consumptions of bagasse and husk are forecasted to increase, and fuelwood will be still consumed in various industries especially in rural areas.

Table II-6 : Energy Consumption by Industry Sector

(KTOE)

	1986	1991	1996	2001	Average Growth Rate 1986-1991	1991-1996	1996-2001	1986-2001
LPG	98	121	139	162	4.3	3.4	2.5	3.4
Diesel Oil	303	428	557	725	7.2	5.4	5.4	6.0
Kerosene	21	17	15	11	-4.1	-8.3	0.0	-4.2
Fuel Oil	1,507	1,829	2,205	2,567	4.2	3.2	3.1	3.5
Natural Gas	192	336	391	455	14.0	3.1	3.1	6.0
Coal	182	310	416	582	11.2	6.1	6.9	8.1
Lignite	262	493	722	1,025	10.7	10.6	7.3	9.5
Electricity	817	1,104	1,385	1,723	6.2	4.6	4.4	5.1
Sub Total	3,383	4,638	5,830	7,250	6.5	4.7	4.4	5.2
Traditional Energy	1,947	2,163	2,309	2,499	2.1	1.3	1.6	1.7
Total	5,330	6,800	8,138	9,750	5.0	3.5	3.7	4.1

Excluding inputs as feedstock

3). Household and Tertiary Sectors

The total end-use demand by these sectors will increase at a low growth rate (2.0%) from 1986 to 2001. However, the demand for modern energy will increase at 5.7% per year which is higher than the growth rate of the demand of the whole country. The demand for electricity will increase 6.9% per year in the same period. The share of modern energy in the total end-use energy demand will increase from 26% in 1986 to 46% in 2001. This means that the substitution from traditional energy to modern energy will be substantially promoted and that in terms of useful energy the growth rate of the total demand can be considered higher than that shown above.

Table II-7 : Energy Consumption by Household-Tertiary Sector

(KTOE)

	1986	1991	1996	2001	Average Growth Rate 1986-1991	1991-1996	1996-2001	1986-2001
LPG	330	448	556	666	6.3	4.4	3.7	4.8
Gasoline	62	78	101	110	5.7	5.3	1.7	4.2
Diesel	88	116	153	174	5.7	5.7	2.6	4.6
Kerosene	170	166	137	76	0.2	-3.8	-11.1	-5.0
Fuel Oil	14	24	36	51	11.4	8.4	7.2	9.0
Electricity	1,020	1,550	2,098	2,789	8.7	6.2	5.9	6.9
Others	0	1	1	1	-	0.0	0.0	0.0
Sub Total	1,676	2,382	3,082	3,867	7.3	5.3	4.6	5.7
Tradition Energy	4,644	4,667	4,677	4,620	0.1	0.0	-0.2	-0.0
Total	6,320	7,049	7,759	8,487	2.2	1.9	1.8	2.0

4). <u>Agriculture and Fishery Sectors</u>

The total demand by this sector will increase at a relatively low growth rate (2.9%) from 1986 to 2001. And, diesel oil will remain to occupy most of it. This corresponds to the growth rate of these sectors (the growth rate of the value added in these sectors are assumed to be a little less than 3% per year in the same period).

Table II-8 : Energy Consumption by Agriculture and Fishery

(KTOE)

	1986	1991	1996	2001	Average Growth Rate 1986 -1991	1991 -1996	1996 -2001	1986 -2001
LPG	12	12	13	14	0.0	1.6	1.5	1.0
Regular Gasoline	39	54	67	81	6.7	4.4	3.9	5.0
Diesel Oil	1,093	1,314	1,487	1,669	3.8	2.5	2.3	2.9
Fuel Oil	3	3	4	4	0.0	5.9	0.0	1.9
Electricity	7	9	12	14	5.2	5.9	3.1	4.7
Total	1,154	1,392	1,583	1,782	3.8	2.6	2.4	2.9

Finally, it should be noticed again that the forecasts, not only for these sectors, by Base Case should be considered as ones projected without taking into account fully conservation or improvement of efficiency of energy consumption, and substitutions between types of energy through price changes or technological changes.

III. Electricity Generation Sector

The electricity generation sector will continue to be one of the key sectors in the viewpoint of energy policy in this country.

The total demand for electricity will increase at higher growth rates than the other types of energy both in the household sector and in the industry and commercial sector. To meet the demand, the electricity sector requires large amount of investment. Moreover, this sector is in a nodal position in the sence that it uses various types of primary energy and transform them to electricity, and it can select combinations of fuel inputs with a broad range of substitution. And accordingly this sector affects largely conditions for the development of the other energy sectors, such as natural gas, lignite supply sectors.

1. Electricity Demand and Total Generation Requirement

Table III-1 and 2 show the forecasts of demand and generation of electricity by EMP Base Case and Load Forecast Working Group[1].

Total electricity demand is forecasted to increase at 6.2% per annum from 1986 to 2001 in Base Case. This forecast is very close to that by the Working Group. The growth rate will be lower than 15.7% in the 1970's and 8.8% in the first half of 1980's. However, the future growth rates of electricity

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1) Load Forecast Working Group for Power Tarrif Study Sub-Committee, Load Forecast for Thailand Electric System, 1986.

Table III-1 : Electricity Balance Demand and Generation (ENP)

Demand/Generation	1984 act.	1986	1987	1989	1991	1996	2001	1984-86	1986-91	1991-96	1996-2001	1996-2001
Electricity Demand (GWH)	18,572	21,701	23,485	27,157	31,357	41,108	55,217	8.63	7.66	5.44	5.49	6.18
Peak Demand (MW)	(3,580)	4,028	4,359	5,041	5,820	7,630	9,885	8.85	7.61	5.06	5.87	6.18
Load Factor of Demand (%)	(61.7)	61.5	61.5	61.5	61.5	61.5	61.5					
Electricity Generation (GWH)	(21,066)	23,045	26,023	29,807	24,760	45,857	59,370	6.84	7.65	5.70	5.30	6.21
Peak Generation (MW)	(3,547)	4,464	4,830	5,447	6,447	8,183	10,698	12.17	7.63	4.89	5.51	6.00
Load Factor of Generation (%)	(67.8)	61.5	61.5	62.8	61.5	64.0	63.4					
Installed Capacity (MW)	5,855	6,675	6,927	7,319	7,635	9,305	12,195					
Electricity Imports (GWH)	699	888	886	835	815	765	715					

Table III-2 : Electricity Balance Demand and Generation by EGAT

Demand/Generation	1984	1986	1987	1989	1991	1996	2001	1984-86	1986-91	1991-96	1996-2001	1996-2001
Electricity Demand (GWH)	19,362	23,744	26,168	30,532	34,582	45,140	58,179	10.73	7.81	5.47	5.19	6.15
Peak Demand (MW)	3,580	4,390	4,812	5,555	6,262	8,309	10,813	10.74	7.36	5.82	5.44	6.19
Load Factor of Demand (%)	61.7	61.7	62.1	62.7	63.0	62.0	61.4					
Electricity Generation (GWH)	21,066	25,747	28,261	32,975	37,349	49,558	64,587	10.55	7.72	5.82	5.44	6.32
Peak Generation (MW)	3,547	4,346	4,764	5,500	6,199	8,225	10,705	10.69	7.36	5.82	5.41	6.19
Load Factor of Generation (%)	67.8	67.6	67.7	68.4	68.8	68.8	68.9					
Installed Capacity (MW)	5,855	6,644	6,884	7,259	7,559	9,574	12,144					

demand are still high compared with the demands for the other types of energy.

Reflecting the economic growth rates 4.2% - 4.9% in the forecasting period, the electricity demand will increase still at relatively high rates both in the industry and the household-tertially sectors, in spite of the fact that GDP elasticities of electricity consumption by sector are forecasted to decrease sustantially shown in Table III-3[2].

Table III-3 : GDP Elasticities of Electricity Consumption

<table>
<tr><th></th><th>1977-1981</th><th>1981-1985</th><th>1986-1991</th><th>1991-1996</th><th>1996-2001</th></tr>
<tr><td>Industry *)</td><td>1.50</td><td>1.41</td><td>1.27</td><td>1.02</td><td>1.06</td></tr>
<tr><td>Commercial</td><td>0.38</td><td>2.27</td><td rowspan="2">1.78</td><td rowspan="2">1.38</td><td rowspan="2">1.40</td></tr>
<tr><td>Residential</td><td>1.72</td><td>2.58</td></tr>
<tr><td>Total</td><td>1.22</td><td>1.93</td><td>1.56</td><td>1.24</td><td>1.26</td></tr>
</table>

*) Include other consumptions

Total electricity generation increase at a little higher growth rate (6.2%) than demand. This is because the low voltage demand, supply for which is accompanied with larger loss, increases at a higher rate than the middle voltage demand in EMP forecast.

Load factor of electricity demand is assumed to be constant

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2) The new macro-economic forecasts by NESDB and the projection of crude oil price by World Bank are used as exogenous variables.

at the level of 1986 (61.5%) throughout the period. This assumption is similar to load factor on the EGAT system forecasted by Load Forecast Working Group. As the load factor is constant, peak demand increases at the same rate as the total electricity demand[3].

To meet this demand, installed capacity of generation increase at 3.7% per annum which is lower than the growth rate of total generation, as the load factor of generation increases (from 61.5% in 1986 to 63.4% in 2001). Total installed capacity in 2001 is forecasted to be 12,195 MW which is slightly larger than that by the Forecast. From 1986 to 2001, capacity of 7,658 MW is required to be installed.

2. Fuel Prices and Generating Cost

Price changes of fuels affect the comparative cost advantages of types of plant, and change the optimized results for capacity expansion in the electricity sector.

Figure III-1 shows relative shadow prices of fuels for electricity generation to the shadow price of imported heavy

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3) The definitions in forecasts by EMP and those by the Working Group are different each other, as follows.

in EMP forecast

electricity demand	: total final consumption
electricity generation	: total electricity generation excluding station service requirement

in the Load Forecast

electricity demand	: sales by EGAT
electricity generation	: electricity generation including station service requirement by EGAT

So, we cannot compare the two Forecasts in absolute value directly.

crude oil. And Table III-4 shows generation costs by type of plant for base load generation calculated using the shadow prices.

In 1986, the relative price of fuel oil to the other fuels is still relatively low. However, it increses up to 1991. The cost advantage of fuel oil which is relatively high in electricity geeration decrease in a short time. At 1991 fuel oil will be the most expensive fuel.

In 1996, natural gas is one of the cheapest fuel for electricity generation, however the relative price of it to the other fuel prices gradually increases because of new investments. After 2001 natural gas will lose it's cost advantage gradually, and coal will become most economic.

Based on Table III-4, we can get the ranking of the four fuels according to their generation costs by the cheapest plants for each fuel as follows :

	1	2	3	4
1986	G	O	C	L
1991	(C	G)	O	L
1996	G	C	L	O
2001	C	G	L	O

In 1986, the ranking of plant type by generation cost is natural gas, fuel oil, coal and lignite from the lowest. In the long-run, the substantial change of the ranking is that fuel oil descends from the second lowest to the highest after 1996. Although natural gas becomes the cheapest fuel for generation in

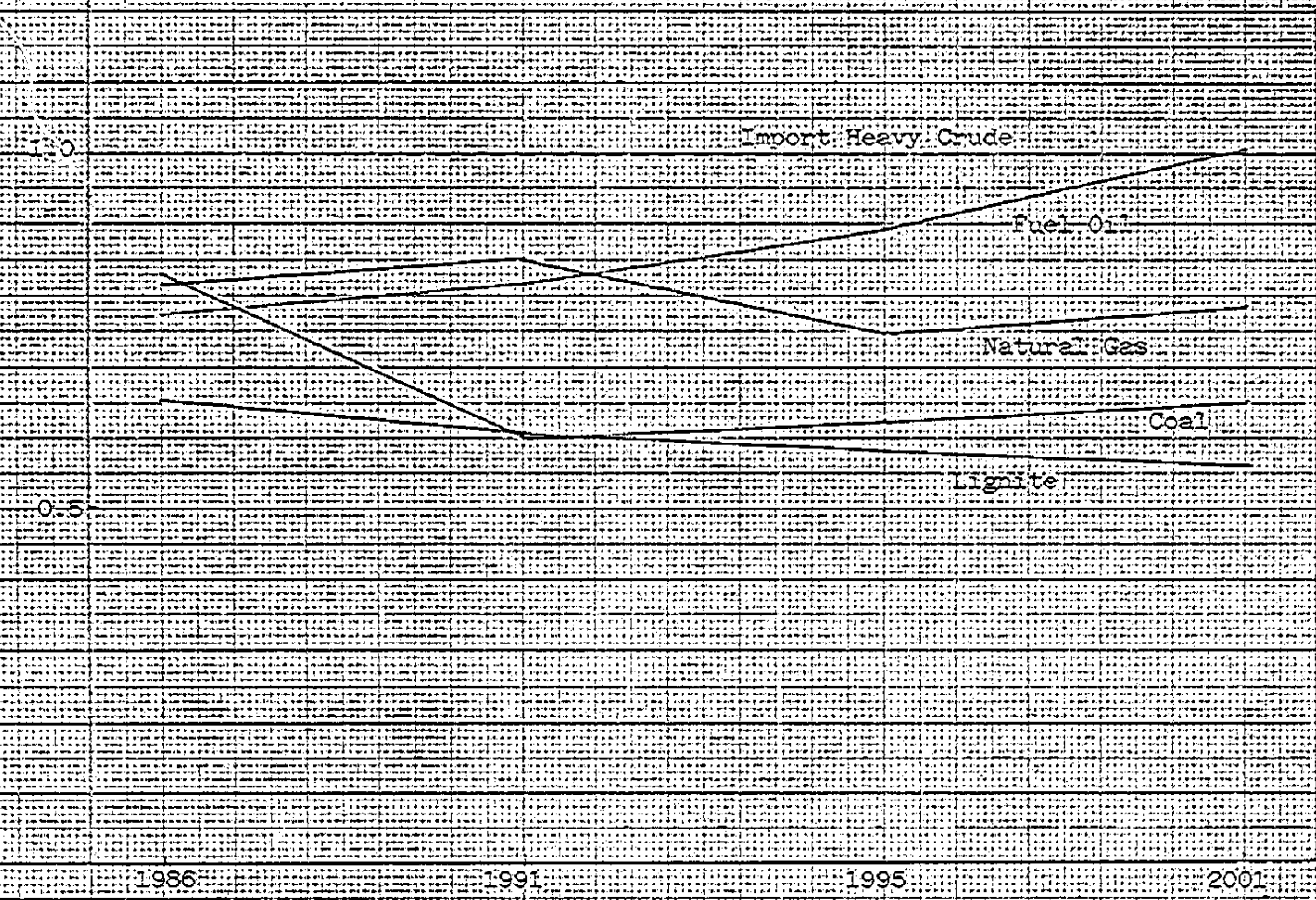


Figure III-1 Relative Shadow Prices of Fuels for Electricity Sector

Table III-4 : Generating Costs by Type of Plant

(1986 US$/KWh)

	1986	1991	1996	2001
Lignite-Fired				
Fuel Cost	0.0160	0.0215	0.0239	0.0267
Othr Costs	0.0291	0.0291	0.0291	0.0291
Total	0.0451	0.0506	0.0530	0.0559
Oil-Gas-Fired				
Fuel Cost (oil)	0.0173	0.0266	0.0338	0.0442
(gas)	0.0174	0.0266	0.0269	0.0328
Other Costs	0.0218	0.0218	0.0218	0.0218
Total (oil)	0.0391	0.0484	0.0556	0.0660
(gas)	0.0392	0.0484	0.0487	0.0546
Oil-Gas-Fried R3				
Fuel Cost (oil)	0.0173	0.0266	0.0338	0.0442
(gas)	0.0174	0.0266	0.0269	0.0328
Other Costs	0.0252	0.0252	0.0252	0.0252
Total (oil)	0.0425	0.0518	0.0590	0.0694
(gas)	0.0426	0.0518	0.0521	0.0580
Coal Fired				
Fuel Cost	0.0188	0.0200	0.0238	0.0288
Other Costs	0.0236	0.0236	0.0236	0.0236
Total	0.0424	0.0436	0.0474	0.0524
Gas-Combined Cycle				
Fuel Cost	0.0167	0.0256	0.0259	0.0315
Other Costs	0.0215	0.0215	0.0215	0.0215
Total	0.0382	0.0471	0.0474	0.0530
Gas-Combined Cycle R3				
Fuel Cost	0.0167	0.0256	0.0259	0.0315
Other Costs	0.0293	0.0293	0.0293	0.0293
Total	0.0460	0.0549	0.0552	0.0609

1996, in the long run coal will be the cheapest.

3. Capacity Expansion Plan

As inputted values for the import prices and domestic supply costs in the Base Case are set as the most probable forecasts (or assumptions), the optimized results for capacity expansion can be considered as a recommended plan in the viewpoint of minimizing the total energy supply cost for this country.

Table III-5 shows the additional capacity expansions by type of plant. In the Base Case run, plants whose installment have already started are set to be accomplished as planned without regard to the relative price changes of fuels. So, lignite-fired plants, Mae Moh #8 and hydro plants, Srinagarind #4, Chiew Larn #1~3 and some other plants are constructed in the period until 1990. These capacity expansions are not necessarily optimal, because the relative prices might have changed from those based on which the EGAT's actual expansion plan was determined.

After 1991, the capacity expansions are determined by optimization under some constraints such as limitation caused by site availability, etc.

The increases of generation capacities by type determined by Base Case are as follows. As for thermal plants, until 1991 large capacity of lignite-fired plants are installed. However after that, as this type of plant is not economic, there is no installation of this type of plant. After 1996, plant types to be installed are diversified. Natural gas combined cycle plants

Table III-5 : Additional Capacity Expansions

Unit : MW

Power Plant Types	1986	1987	1989	1991	1996	2001	
Hydro Power Plant							
Large 1	180	0	0	0	180	0	Srinagarind #4 (180 MW), Srinagarind #5 (180 MW)
Large 2	0	240	0	0	580	80	Chiew Larn # 1-3 (240 MW), Nam Chon #1-4 (580 MW), Krang Krung (80 MW)
Large 3	0	0	0	0	0	290	Nam Mae Yuam (160 MW), Mae Chaem (130 MW)
Medium 1	0	0	0	0	0	0	
Medium 2	21	0	0	0	0	46	Mae Ngat # 1-2 (9 MW), Huai Saphan Hin # 1-2 (12 MW), Sai Buri (46 MW)
Medium 3	0	0	0	0	0	0	
Sub Total	201	240	0	0	760	416	
Micro	0.1	0.1	0.2	0.2	0.5	0.5	
Mini	9	12.1	17.1	15.6	30	30	
Sub Total	9.1	12.2	17.3	15.8	30.5	30.5	
Thermal Power Plant							
Coal	0	0	0	0	600	1950	AO Phai #1-4 (4*600 MW), Krabi (150 MW)
Dendro	0	0	0	0	0	0	
Lignite	300	0	300	300	0	0	Mae Moh # 6-7 (2*150 MW), Mae Moh #8 (300 MW), Mae Moh #9 (300 MW)
Nuclear	0	0	0	0	0	0	
Oil/Gas/Coal	0	0	0	0	0	0	
Oil/Gas	0	0	0	0	0	1200	New Plants (2*600 MW)
Oil/Gas-R3	0	0	75	0	0	0	Khanom Barge #2 (75 MW)
Combined Cycle-R	0	0	0	0	300	300	Khanom Block 1-4 (4*150 MW)
Combined Cycle	0	0	0	0	300	300	Nam Pong Block 1-2 (2*300 MW)
Gas Turbine	0	0	0	0	0	0	
Diesel	0	0	0	0	0	0	
Sub Total	300	0	375	300	1200	3750	
Total	510.1	252.2	392.3	315.8	1990.5	4196.5	

(1200 MW) and a coal-fired plant (600 MW) are installed. And in 2001, coal-fired plants (1800 MW) and oil-gas-fired plants (1200 MW) are installed.

As for hydro plants, in 1996 after 10 years Srinagarind #4 and Chiew Larn #1-3 are installed, large capacity (Srinagarind #5, etc.) will be installed.

All types of thermal plants are used for base load generation, except that some types (combined cycle R3 etc.) are occasionally used for peak load generation. Peak load generation is borne largely by hydro-power plants whose utility factor is low.

Comparing this recommended plan with the plan by EGAT for example in 2001, the compositions by type of plant by two forecasts are different in the following way. Capacities of hydro plants are close each other. However, capacities of coal-fired and lignite fired plants are small by EMP forecasts than by the Working Group's forecasts, and as for the other types of plant EMP forecasts are larger. And these distortion may be explained, by that EMP forecasts take into consideration the relatively low prices of petroleum products and natural gas from 1986.

4. Implications for Policy

Some implications for policy are derived from the Base Case results.

Lignite-fired plant currently existing and under construction do not have cost advantage for the period at least from 1986 to arround 1991. If it is desirable to assure lignite-fired plants of economic viability, some policy, for example subsidy to EGAT, may be needed.

More broadly speaking, by the price decline of imported energy, supply of every indigenous energy not only lignite will be more or less suppressed. So, if policy should place stress on promoting supply of indigenous energy and decreasing import of energy, some policy should be pursued to make indigenous energy economic for supplier and consumers. In the long run import price of coal will become the base for the pricing of indigenous energy. To make them competitive with coal, subsidies may be necessary for their supplies. Costs to do this must be loaded on the government or some industries, and indirectly on the whole economy.

IV. Oil Refinery Sector

In the past several years, world oil market has been glut, and also is forecasted to be so at least in the short-run. The drastic decline of oil price made oil importing countries to be able to save large amounts of foreign exchanges.

However, in the long-run, consumption of petroleum products will still shares large in the total consumption in this country as in the other countries. World oil market will become tight, and oil price will increase at a higher rate in the long-run than in the short-run. By this reason, policies on the demand management of petroleum products and on the optimization of investments in the energy supply sectors should be implemented in the long-run viewpoints.

1. Demands for Petroleum Products and Domestic Production

Table IV-1 shows forecasts of gross consumption of petroleum products by the Base Case. Total demand is forecasted to increase at 3.8% per annum from 1986 to 2001, which is higher than the stagnant growth rate in the recent several years, but substantially lower than until 1970's.

Table IV-1 : Gross Consumption of Petroleum Products

(Tcal)

	1986	1991	1996	2001	Averae Annual Growth Rate
LPG	7,371.4	9,648.4	11,667.1	13,939.0	4.3
Gasoline	17,812.9	23,523.0	29,282.2	35,844.1	4.8
Kerosene and jet fuel	12,254.8	15,183.8	18,494.7	22,093.0	4.0
Diesel	49,595.7	64,524.0	78,417.8	94,265.0	4.4
Fuel oil	24,763.2	23,880.2	26,683.5	31,532.9	1.6
Bitumen	1,448.0	1,491.0	1,523.0	1,555.0	0.5
Total	113,246.0	138,250.4	166,068.3	199,229.0	3.8

Growth rates of demands by type of energy change also from the recent ones. The demand for gasoline is forecasted to increase at a higher rate than before, and that for diesel oil at a lower rate, reflecting the adjustment of the retail prices to their international prices. However, the demand for diesel oil increases in the largest volume among petroleum products and still occupies a little less than 50% of the total demand.

The demand for fuel oil is forecasted to increase again in 1990's mainly in the industrial sectors.

Production of petroleum products will increase, and the yield structure will also change by modifying configurations of existing refineries and installment of one new refinery as mentioned below. By these capacity expansions, the share of imports in the total demand of petroleum products will remain in a relatively low level around 30% until 1996, though it will increase after that (Table IV-2).

Table IV-2 : Production and Import of Petroleum Products

(BCD)

	1986	1991	1996	2001
Refinery Output				
LPG	4,926	7,630	10,808	10,621
Gasoline	40,022	42,005	51,266	50,204
Kerosene and Jet fuel	17,905	19,306	31,692	31,830
Diesel	52,882	63,941	91,280	90,738
Fuel Oil	42,819	43,321	48,400	49,920
Bitumen	2,536	2,611	2,667	2,723
Total	161,091	178,814	236,113	236,037
Import				
LPG	0	0	2,292	8,630
Gasoline	793	11,889	15,820	31,927
Kerosene and Jet Fuel	7,683	12,405	6,941	14,315
Diesel	45,355	63,853	64,032	95,978
Fuel Oil	2,109	0	0	7,278
Bitumen	0	0	0	0
Total	55,940	88,149	89,084	158,132

*) Includes outputs of the natural gas sector

In spite of the production increases of middle distillates (diesel oil, jet fuel, etc.) by the modifications of yield structure, imports of these products take a large part of the total import. As for fuel oil, the Base Case results show that production of it will increase by using heavy crude as inputs and by the modifications of the configurations of refineries. Consequently the total demand for fuel oil will be met by the domestic supply, from 1991 to 1996.

2. Refinery Capacity Expansions

There are two major factors which determine expansion of refinery capacities.

One is the volume and composition by type of product of demands. Especially the composition of domestic demands will be one of the major factors which determine the configurations of refineries. In this country, diesel oil continues to be in short most seriously among products, and the demand for fuel oil will decrease relatively. How to meet the demand structure like this by expansions and modifications of configurations of refinery capacity, is an important planning issue in this sector.

The second is the world market condition of petroleum products. If, in the world market, excess refinery capacities exist and the difference between prices of petroleum products and their costs become relatively small, the profitability of investment on new refineries will decrease. And to import petroleum products becomes more advantageous than to produce them domestically. How much percentage of total demands of petroleum products should be produced domestically depends largely on how long and how much the excess capacity remains in the future.

Capacity expansions by Base Case are shown in Table IV-3. Until 1991, capacity increase will consist of that brought by TORC's actual expansion plan and somo modifications of the other existing refineries. And after 1991 it is brought mainly by a new refinery whose capacity of crude unit is 65,200 BCD. The capacity expansions for the other types of unit are vaccum unit (34,600 BCD), solvent deasphalting unit (19,700 BCD), hydrocracking unit (43,300 BCD) and reforming unit (2,300 BCD). And these expansions will be combined with the new crude unit.

Table IV-3 : Refinery Capacity Increases

(BCD)

	1986	1991	1996	2001
Crude Units	183,000	1,500	6,700	6,700
Vacuum Units	23,000	52,600	87,200	87,200
Solvent Deasphalting	0	0	19,700	19,700
Thermal Cracking	20,400	20,400	20,400	20,400
Hydrocracking	0	17,000	60,300	60,300
Reforming	23,600	23,600	25,900	25,900

Table IV-4 : Refinery Output and Composition of Input

	1986	1991	1996	2001
Total Refinery Output (BCD)	161,091	178,814	236,113	236,953
Refinery Inputs (BCD)				
Imported Medium Crude	30,789	88,851	9,868	0
Imported Light Crude	97,035	0	0	0
Domestic Light Crude	20,460	15,520	0	o
Imported Heavy Crude	12,939	69,782	220,489	229,825
Natural Gas Condensate	1,082	2,462	3,189	3,297
Natural Gasoline	1,716	3,002	3,330	3,458
Natural Gas (MMSCFD)	0	7	25	26
Total	164,020	179,616	236,875	236,579
Conversion Efficiency (Outputs/Inputs)				
Calorific	0.9660	0.9771	0.9743	0.9767
Liquid Volume	0.9821	0.9955	0.9968	0.9977

By the optimization of the model, imported heavy crude will increase as refinery input, although imported medium crude and domestic light crude are consumed until arround 1996 and 1991 respectively. Natural gas, condensate and some other by-products are inputted to refineries. The total of them amounts to 5% of the total input in 2001.

It must be noticed that the simulation results on oil refinery sector should be regarded carefully. Because the optimized results on the refinery capacity expansions and input structure may change very sensitively according to the price differentials among types of crude, and relative prices of products to crude oil prices.

3. Policy Implications

In the Base Case run, the total refinery capacity of crude unit is determined by setting constraints which can be considered as ones of the possibly recommended capacity expansion paths. This methodology is adopted by the reason that it is not desirable to determine the recommended expansion plan for the total capacity by optimization without constraints. Because the estimates and forecasts for the input prices, product prices and production costs (especially investment costs) still lack accuracy, the model is too simple to deal the actual issues on the refinery expansions, and , more importantly, the optimal capacity expansions should be determined taking into consideration the other factors such as the security of energy supply which the model cannot deal with.

As for the configurations of refineries the model determines the optimized results without constraints but indirectly constrained by the capacity of crude unit. However, by the same reasons mentioned above, the results should be looked at with much reservation.

For pricing of petroleum products, this model can say only small. The model optimizes the energy demand by type reflecting their shadow prices which are determined by costs excluding tax and subsidy. In this sence the shadow prices for the end users can be said as retail prices when all taxes and subsidies are removed. The results of the Base Case run implies that the demands for diesel oil remain tight even if the retail prices of petroleum products are determined reflecting costs.

V. Natural Gas Sector

Supply and utilization of natural gas are the outstanding policy issues in the immediate future. The directions of policies concerning natural gas have large influences on the economy's future as well as the supply-demand structure of energy of this country. The policies should be determined in the viewpoint of not only the conditions for its supply and demand, but also as indigenous energy the influences on the supply-demand conditions of the other energies, on the total import of energy, and on the future economic development.

1. Demands for Natural Gas

Forecasts of supply-demand balance of natural gas (by Base Case) are shown in Table V-1. The total supply is forecasted to increase from 350 MMSCFD in 1986 to 874 MMSCFD in 1996, and to decrease slightly to 856 MMSCFD in 2001. According to the Base Case results, total supply of natural gas and its products (LPG, etc.) is absorbed domestically. The largest quantity is consumed in the electricity sector throughout the period. It will increase from 23,400 Tcal in 1986 to 55,700 Tcal in 1996 and remain arround that level up to 2001. The share of consumption by the electricity sector in the total consumption will continue to be above 65%. The demand by industry as fuel (only cement industry is considered as consumer) will increase from 1,700 Tcal in 1986 to 3,200 Tcal in 2001.

Table V-1 : Natural Gas Supply-Demand Balance

(Tcal)

	1986	1991	1996	2001
1. Gas Supply (MMSCFD)	31,682 (350)	65,184 (720)	79,170 (874)	77,485 (856)
2. Disappearance				
Fuel Uses	31,680	57,463	69,837	68,135
EGAT	23,435	44,113	55,733	53,305
LPG *)	5,554	8,317	8,317	8,317
Cement Indust.	1,708	2,197	2,666	3,210
Natural Gasolene	749	1,310	1,453	1,509
Other Fuel	234	1,526	1,668	1,794
Feedstock Uses	0	7,721	9,333	9,349
Ethylene	0	4,334	4,334	4,334
Refinery Hydro	0	672	2,284	2,300
Methanol	0	2,715	2,715	2,715

*) Includes feedstock use

Production of LPG from natural gas will increase from 5,600 Tcal in 1986 to 8,300 in 1991 and remain at this level until 2001, as the capacity of the gas separation plant is assumed to increase to 500 MMSCFD in 1991 from the present capacity of 350 MMSCFD.

The other usages are for feedstock. As feedstock users, the petrochemical plant and the fertilizer plant are assumed to start operation in 1989. Summing up the stock demands by the refineries and by the two new users, the total demand for natural gas as feedstock will increase from 7,700 Tcal in 1991 to 9,300 Tcal in 2001.

End-use demands for LPG are shown in Table V-2. Demands by household-tertiary and transport sectors are forecasted to increase at high growth rates such as 4.8% and 4.2% respectively from 1986 to 2001. This is because the natural gas price, consequently the LPG price are forecasted to be relatively stable compared to crude oil price and petroleum product prices. In Base Case by the higher growth rate of the demand than the supply, import of LPG is forecasted to take place arround 1996.

As for condensate a large part of it will be exported, excepting feedstock to refineries.

Table V-2 : End-Use Demands for LPG by Sector

(Tcal)

	1986	1991	1996	2001
Agriculture,Fishery	116.6	124.8	133.7	142.2
Industry	986.3	1,222.8	1,441.2	1,635.3
Household-Tertiary	3,335.1	4,519.0	5,607.1	6,722.5
Transport	2,933.4	3,781.8	4,485.1	5,439.0
Total	7,371.4	9,648.4	11,667.1	13,939.0

2. Capacity Expansions

Table V-3 shows natural gas supplies by field. Supply from Block 10-13 will continue to increase and occupy at least about half of the total supply throughout the period. Supply from

Texas B will increase in the first half of 1990's. Onshore supply by Esso and Shell will be at the peak arround 1996.

Table V-3 : Natural Gas Supplies by Field

(MMSCFD)

	1986	1991	1996	2001
Erawan	125	100	50	
Block 10-13	200	400	450	500
Texas B		100	195	246
Offshore Total	325	600	695	746
Esso		100	175	110
Shell	25	20	4	
Onshore Total	25	120	179	110
Total	350	720	874	856

These supplies will be assured until arround 1991 by the contracts already concluded. However, after that new contracts are required to be concluded to assure the supply enough to meet the demand.

For transportation and processing, required capacity expansions are shown in Table V-4. The pipeline from ESSO to EGAT's power plants will start operation in 1989. And the pipelines from Texas B fields to the Union platform and from the Union platform to Khanon will be completed in 1996. The gas separation plant will increase its capacity from 350 MMSCFD to 500 MMSCFD in 1991. Compressors will be installed at Erawan platform in 1991 to boost the pressure to increase supply capacity.

Table V-4 : Capacity Expansions of Pipelines and Processing Facilities

	Capacity (Incremental Capacity)		Year of Commissioning
Pipeline	MMSCFD	(MMSCFD)	
Texas B - Union Platform	250	(250)	1991
Union Platfrom - Khanon	60	(60)	1996
Esso - EGAT Power Plants	17.5	(17.5)	1989
Compressor	230	(230)	1991
Gas Separation Plant	500	(150)	1991

3. Policy Implications

It must be noted that, in EMP model, the deliverbility of natural gas is given exogenously. And it is assumed that increasing supplies to meet the demand is possible through exploration efforts which will be taken under the present pricing system of weel-head price. The adequacy of this assumption must be examined besides the analyses on the results of runs. Namely how the supply (or exploration) of natural gas will be affected by the recent price declines of the imported energies and how it can be promoted in the future are left to analysed.

On the other hand, natural gas will be more economic than coal and lignite for consumers (at least for the electricity sector) in Base Case. This means that well-head prices and prices at the steps to the end-use consumers of natural gas can be fixed at some optimal level within certain range between supply cost and opportunity cost of it, taking into consideration the promotion of not only consumption but also exploration and supply.

VI. Lignite and Coal

By the recent declines of petroleum products prices, lignite and coal have decreased their cost advantages to the former (especially fuel oil), and their relatively high prices are forecasted to continue until arround 2001 in Base Case. However, in the long-run, prices of hydrocarbons will increase at relatively higher rates, and coal and lignite will become more economic.

Forecasts of demands for coal and lignite are shown in Table VI-1. The electricity sector will continue to be a main consumer of coal and lignite. As for coal, the consumption by the electricity sector starts in 1996, and reaches to 4.3 million toe by the power plants of 2400 MW at Ao Phai in 2001. The consumption of lignite by the electricity sector will increase to 10.5 million ton by the power plants of 1485 MW at Mae Moe and Krabi until 1991, and remain at this level throughout the period.

Table IV-1 : Demands for Coal and Lignite

(KTON)

	1986	1991	1996	2001
Coal				
Industry	292	496	666	932
Electricity	0	0	1,605	6,825
Total	292	496	2,271	7,757
Lignite				
Industry	602	1,001	1,655	2,350
Electricity	5,320	9,000	10,060	10,076
Total	5,922	10,001	11,715	12,426

Consumptions of lignite and coal by industries will increase gradually. The largest parts of the consumptions are by the cement industry, whose shares in the total consumptions by the industrial sector will attain above 50% in 2001.

The increases of demands are forecasted reflecting the long-run declines of relative prices of these fuels. And also the demand forecasts in Base Case especially for lignite by the industrial sector should be considered possible by the additional costs to promote consumption such as beneficiations (briquetting, for example) and subsidies (to consumers, for example), which are not considered explicitly in the model.

As for the supply side of lignite, the demand by the electricity sector will be satisfied mainly by Mae Moe, and the demand by the industrial sector will be met by Li-Khon and Tip.

For increasing supply of coal, the large investment required is for coal unloading port facilities, especially to supply it to EGAT's power plants at Ao Phai.

Finally, it should be noticed that, to prepare for the future, implementing plans for supply and consumption of lignite and coal in the long term viewpoint are needed. The Base Case forecasts present a possible course in the viewpoint of long term optimized supply policies of energy.

VII. Traditional Energy

In EMP Model, the supplies of traditional energy are determined directly by their demands. The model does not take into consideration the cost advantages through optimization. Accordingly the forecasts of the supplies of these types of energy should be considered as on of the possible targets for their supplies. And policies for the supply and consumption of them should be developed by studies outside the model.

Here some implications of the forecasts can be presented. The supply of charcoal and fuelwood will be required to be stable until 2001. These fuels will be still economic and main energy source in household in rural areas. Important policy issues concerning these fuels are as follows. The supply must be accompanied with the efforts for conservation and development of the resources, and these efforts are required especially in the areas like the Northeast where the demand will be still large and the resources are going to deplete. On the other hand, as the supply depends on the demand, the another way to evade the problem is to decrease the demands by substitution to the modern energy such as LPG, electricity and other energy. And it is obvious that some subsidies will be required to promote the substitution.

The supply of bagasse and husk as energy sources is forecasted to increase. The agricultural wastes such as bagasse and husk will be used more as energy sources by promoting measures in economic and technological aspects.

Table VII-1 : Demands for Traditional and New Energy

(KTOE)

	1986	1991	1996	2001
Charcoal	2,472	2,578	2,691	2,747
Fuelwood	2,213	2,129	1,967	1,797
Bagasse	1,045	1,212	1,365	1,544
Husk	862	912	963	1,031
Sub Total	6,592	6,831	6,986	7,119
Solar Heat	0.4	0.5	0.6	0.7
Total	6,592	6,832	6,987	7,120

VIII. Analysis on Alternative Scenarios

In this section, analyses on the effects on the optimized results by changing some of the assumptions for Base Case are conducted. And implications on the policy directions corresponding to changes in these assumption will be examined.

1. Alternative Scenarios for Import Prices of Energy

The optimized supply-demand structure of energy is affected by the future movements of prices of energy. As the future prospects of the prices are subject to a great deal of uncertainty, it is useful to examine how the optimized results change if the prices change from the assumptions in Base Case.

Two alternative scenerios of energy prices are set as shown in Table VIII-1. One is Low Price Case where the prices of imported energy and wellhead price of domestic crude increase at the annual growth rates two percents lower than in Base Case from 1987 to 2001. And natural gas prices increase following fuel oil price through the pricing formulas. Another is High Price Case where the import prices increase at the annual growth rates two percent higher than in Base Case. And natural gas prices increase also following the formulas. Lignite prices are not changed in the two cases from Base Case.

These two scenarios present two probable directions of changes of energy prices when the international (import) prices of energy will become high or lower than those by Base Case.

Table VIII-1 : Assumptions of Prices of Selected Fuels for Alternative Scenarios

	Unit	Base Case			Low Price Case		High Price Case	
		1986	2001	Growth Rate	2001	Growth Rate	2001	Growth Rate
Import				%				
Crude Average	US$/BBL	14.44	28.29	4.6	21.29	2.6	37.39	6.5
P.Gasoline	US$/BBL	20.88	40.91	4.6	30.79	2.6	54.07	6.5
Kerosene	US$/BBL	17.28	33.85	4.6	25.47	2.6	44.73	6.5
Jet Fuel	US$/BBL	23.73	46.50	4.6	35.00	2.6	61.45	6.5
H.Diesel	US$/BBL	18.59	36.41	4.6	27.41	2.6	48.13	6.5
Fuel Oil	US$/BBL	10.34	27.01	4.6	20.33	2.6	35.70	6.5
Coal	US$/TON	63.63	59.59	2.1	44.29	0.1	79.72	4.1
Domestic								
Phet Crude	US$/BBL	11.50	22.53	4.6	16.96	2.6	29.77	6.5
Natural Gas (1)	US$/MBTU	2.23	2.26	0.1	1.54	-2.4	3.53	3.1
Lignite (2)	BAHT/TON	475.0	648.8	2.1	648.8	2.1	648.8	2.1

(1) Well-head price at Erawan

(2) For electricity generation

End-use demands of energy by sector do not change among Base Case and the two alternative scenarios. So, it should be noticed that the effects examined by these runs are partial effects of price changes directly affected to the energy sectors without taking into account the effects by the changes of end-use demands and the related indirect effects. By these reasons the following analysis is limitted to the energy sectors.

2. Electricity Sector

The changes of shadow prices by type of fuel are shown in Figure VIII-1. It shows shadow prices of fuels in the electricity sector in 2001 by three alternative scenarios. By the assumptions, prices of indigenous energy will become economic in High Price Case, and not economic in Low Price Case. The largest changes among the three scenarios are for fuel oil, and the seconds are for coal and natural gas. Shadow prices of lignite are very stable among the scenarios.

Figure VIII-2 shows electricity generating costs by type of fuel in 2001 calculated using the shadow prices. According to this, the differences among generating costs by type of fuel become narrower if the prices of imported energy decrease from those in Base Case. And coal and natural gas become economic. If the prices increase, lignite become competitive with coal and natural gas. These pictures in the long run are quite different from the present situation in which fuel oil price is relatively low.

Figure VIII-3 shows cumurative capacity expansions by type of unit from 1986. As the relative cost advantages of fuels change, capacity expansions by type of unit become different among the scenarios. Capacity expansions of lignite-fired plants will be larger in High Prices Case than the other two cases, from 1996. Corresponding to it, those of oil-gas-fired plants by High Prices Case become smaller in 2001. As for combined cycle plants, though there are diffenences among the expansion paths for the three cases, in 2001, the cumulative capacities become same. However, important is that gas-fired combined cycle plants in Region 3 will be converted to use fuel oil not natural gas in Low Price Case, because the pipeline from Union platform to Khanon become uneconomic.

These results indicate that, as the import prices of energy change, substitution takes place between lignite-fired plants and oil-gas fired plants in the long-run. Same thing can be said by Table VIII-2 which shows the consumptions of fuels by type in the electricity sector in 2001. According to this, lignite substitutes for natural gas and fuel oil as the import prices of energy increase.

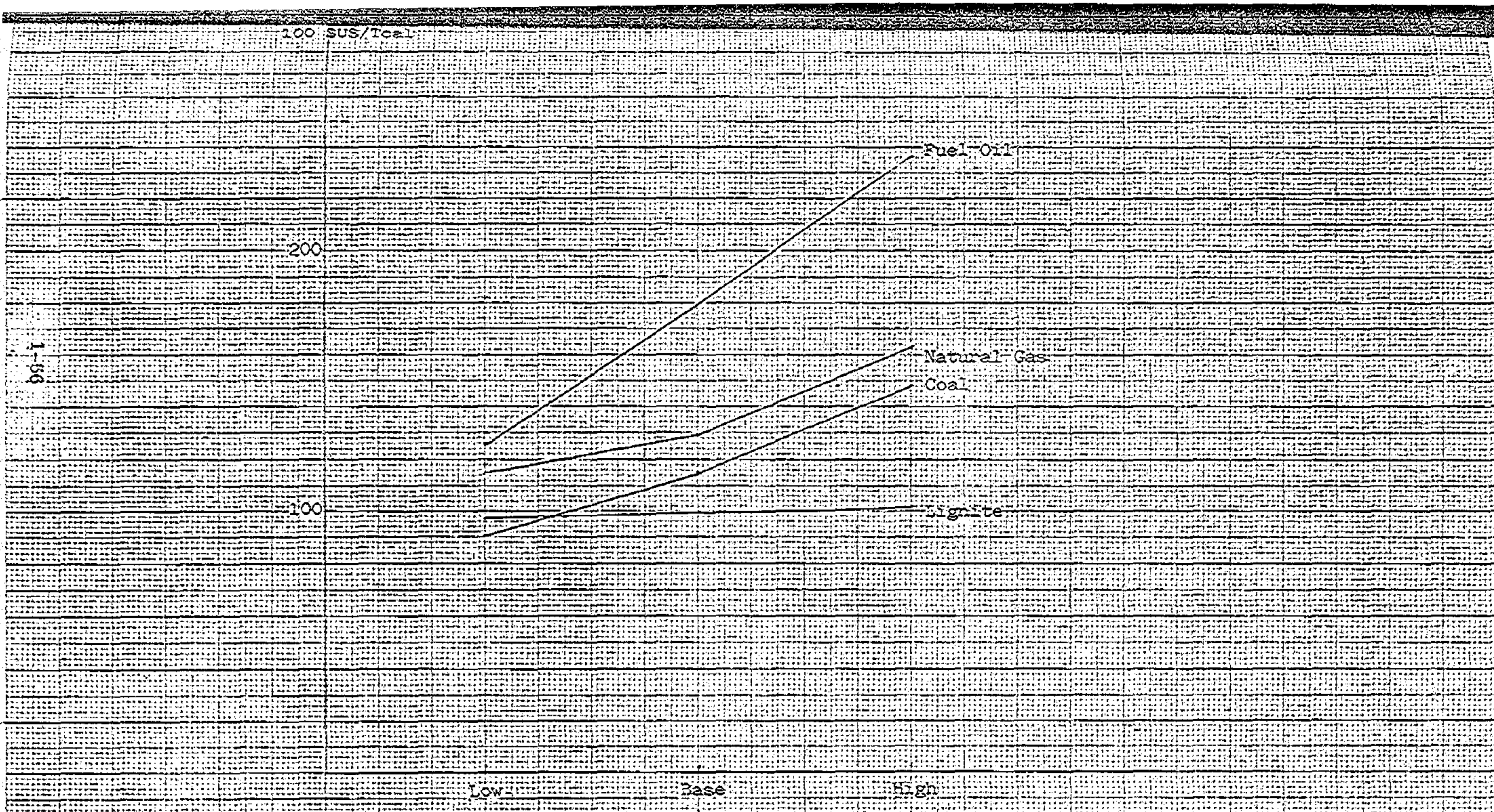


Figure VIII-1 : Shadow Prices of Fuels in the Electricity Sector by Three Alternative Scenarios in 2001.

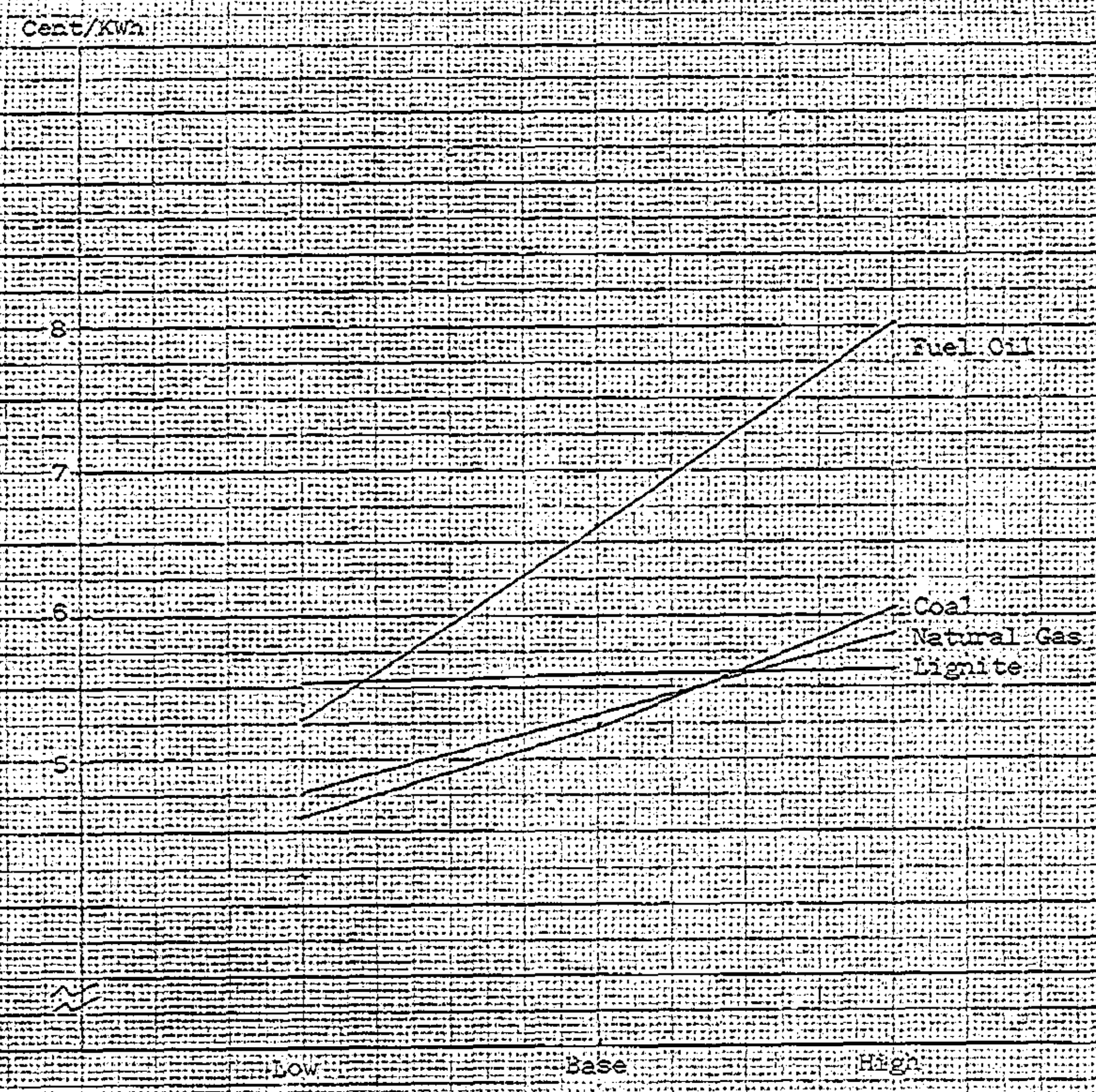


Figure VIII-2 : Generating Costs by Type of Fuel by Three Alternative Scenarios in 2001

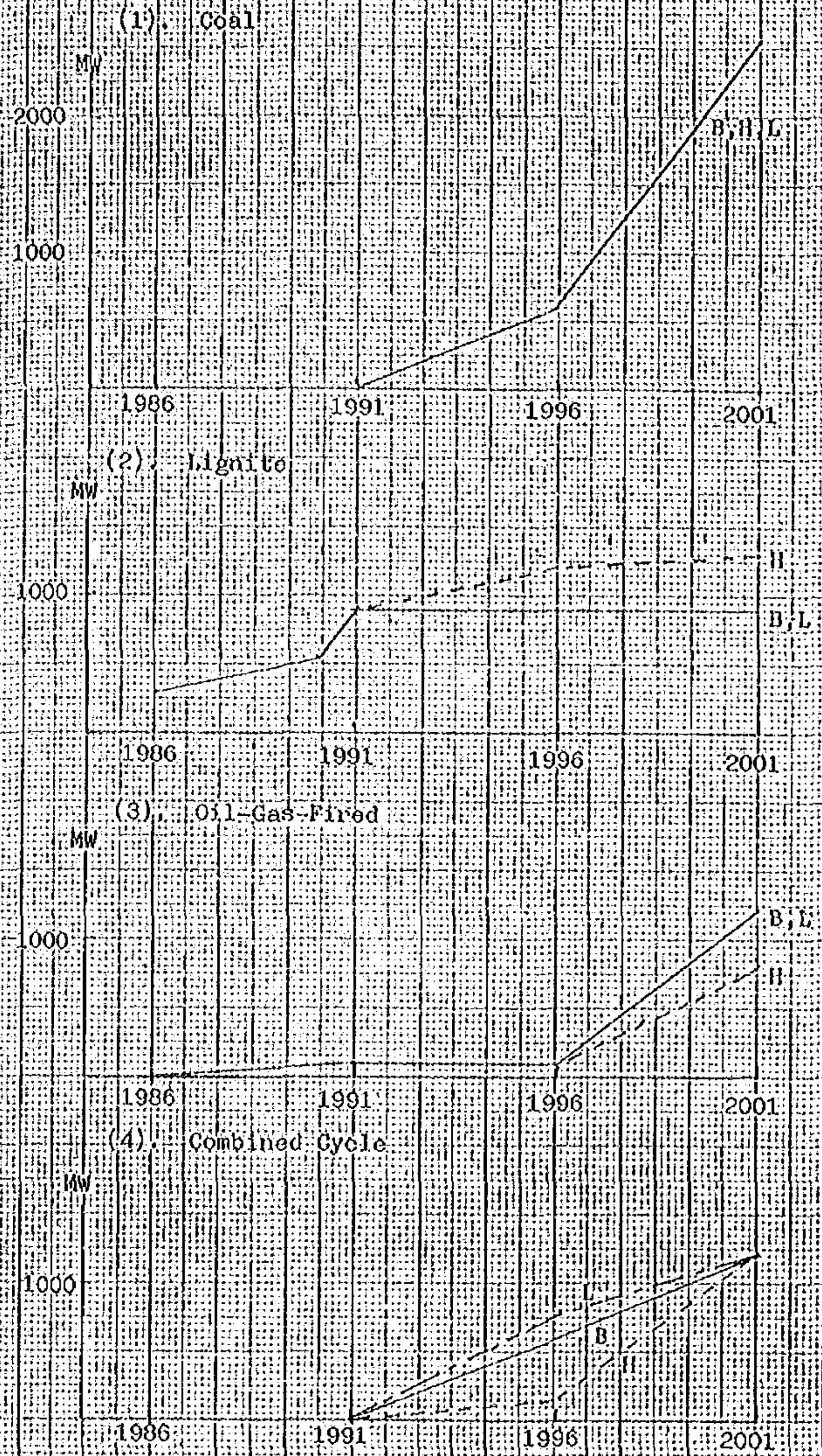


Figure VIII-3 : Cumurative Capacity Expansions by Type of Unit from 1986

B : Base Case, L : Low Price Case, H : High Price Case

Table VIII-2 : Consumption of fuels in the electricity sector in 2001.

(KTOE)

	Low	Base	High
Fuel Oil	362.6	113.9	113.9
	2.6%	0.8%	0.8%
Natural Gas	5,346.8	5,280.4	4,710.0
	37.7%	37.2	32.9
Coal	4,259.8	4,259.8	4,259.8
	30.0%	30.0%	29.8%
Lignite	2,152.2	2,495.9	3,148.9
	15.2%	17.6%	22.0%
Total	12,121.3	12,149.9	12,232.6
	100.0%	100.0%	100.0%

3. Oil Refinery Sector

Table VIII-3 and 4 show the results for the oil refinery sector. Table VIII-3 shows the aggregate refinery capacities by type of unit. As the total capacity of crude units are set constant for three scenarios, the results can reveal only the effects on the capacities of secondary processing units, i.e. vacuum units, solvant deasphalting units, thermal cracking units, hydrocracking units and reforming units. According to this table, the capacities of these units will increase as the import prices of crude oil and petroleum products increase.

As a results, the productions of diesel oil, jet fuel and kerosene will increase, and that of fuel oil will decrease, as shown by Table VIII-4.

Tablo VIII-3 : Aggregate Refinery Capacity in 2001

(BCD)

	Low Price	Base	High Price
Crude Units	266,700	266,700	266,700
Vacuum Units	67,800	87,200	90,800
Solvant Deasphalting	10,300	19,700	18,000
Thermal Cracking	20,400	20,400	23,900
Hydrocracking	41,800	60,300	56,200
Reforming	25,600	25,900	26,900

Table VIII-4 : Productions and Imports of Petroleum Products and crude oil by Alternative Scenarios in 2001.

(BCD)

	Low Price		Base		High Price	
	Production	Import	Production	Import	Production	Import
Petroleum Product						
LPG	10,125	9,127	10,621	8,631	10,231	9,022
Gasoline	49,980	32,153	50,204	31,927	48,992	33,140
Diesel Oil	82,359	104,356	90,738	95,977	92,996	93,721
Jet & Kerosene	28,367	17,779	31,830	14,315	32.845	13,301
Fuel Oil	61,752	0	52,643	7,278	48,019	9,178
Total	232,582	163,415	236,036	158,128	233,083	158,362
Crude Oil						
Light	0	0	0	0	0	0
Medium	0	0	0	0	0	0
Heavy	0	229,699	0	229,825	0	229,680

4. Natural Gas Sector

The supply (demand) of natural gas will decrease as the import prices of energy increase from Base Case, from 1996, and also slightly decrease as they decline. This result corresponds the relative cost advantages of fuels in the three cases and their effects on consumptions especially by the electricity sector. In High Price Case, consumption of natural gas by the electricity sector will decrease because the generation cost by natural gas will become higher than that by lignite. In Low Price Case, the pipeline to Khanon will not be installed because it's feasibility decreases, however total consumption of natural gas will decrease only slightly in 1996 and will be at the same level as Base Case in 2001. This is because the consumption of natural gas by the other gas-fired plants will consume more than in Base Case, and will almost cancel the decrease by the convert of the planned gas-combined cycle plants in Region 3 to fuel oil-fired plants.

Table VIII-6 shows the changes of capacities by the three scenarios. In High Price Case, the required capacity of the pipeline from Texas B to Union platform will become smaller than in Base Case, Because the total demand of natural gas will be smaller. And the capacity of compressors will also become smaller. In Low Price Case, the pipeline from Union platform to Khanon will not be installed, and the capacity of compressors will be larger than in Base Case because the consumption in the central region will be larger.

Table VIII-5 : Total Supply of Natural Gas

(MMSCFD)

	1986	1991	1996	2001
High Price Case	350	720	837	793
Base Case	350	720	875	856
Low Price Case	350	720	857	856

Table VIII-6 : Capacities in Gas Sector

(MMSCFD)

	Low Price Case	Base Case	High Price Case
Pipeline			
Texas B - Union Platform	250	250	190
Union Platform - Khanon	0	60	60
Esso - EGAT Power Plant	17.5	17.5	17.5
Compressor	250	230	170
Gas Separation Plant	500	500	500

PART 2

ENERGY DEMAND ANALYSIS

I. Energy Consumption in the Household and Service Sector

Energy consumption in the household and service sector contribute to the utility (or the welfare) of people directly, while that in the other sectors can only do indirectly through production. In this sence, the increase in quantity and the improvement in quality of energy consumption in this sector can be one of the principal objectives of national energy policy.

The purposes of this paper are, to compile some historical data and outline the recent changes in the energy consumption in this sector, and to analyse mechanisms which determine the energy consumption in this sector.

1. Recent Changes in Energy Consumption

The household and service sector is divided into a urban and a rural sector. However, because of the availability of data, we define "urban" area as the MEA (Metropolitan Electricity Authority) service area, and "rural" area as the PEA (Provincial Electricity Authority) service area. And, although it is desirable to separate household sector and service sector, this is possible only for electricity (details of construction of data will be shown in Annex). So in this study the household and service sector is treated as one sector.

Recent changes in energy consumption in this sector can be outline as follows :

Figure I-1 show the recent movement of total and per capita energy consumptions in the urban and the rural household-service sectors. Total energy consumption in the urban area increased from 6.9×10^{15} kcal in 1979 to 9.7×10^{15} kcal in 1984 by annual growth rate of 7.0%, and that in the rural area increased from 34.6×10^{15} kcal to 43.8×10^{15} kcal by 4.8% in the same period. Per capita consumption in the urban area increased from 1120×10^{3} kcal to 1450×10^{3} kcal by 5.3% per annum, and that in the rural sector increased from 870×10^{3} kcal to 1000×10^{3} kcal by only 2.8% per annum.

Figure I-2 and I-3 show per capita energy consumption by type of energy in the urban and rural sectors. In both sectors, the shift from traditional energy to non-traditional (hereafter, "modern") energy can be seen, but in the rural sector the shift is slow compared with in the urban sector. And the rural sector depends the large part of energy still on the traditional energy.

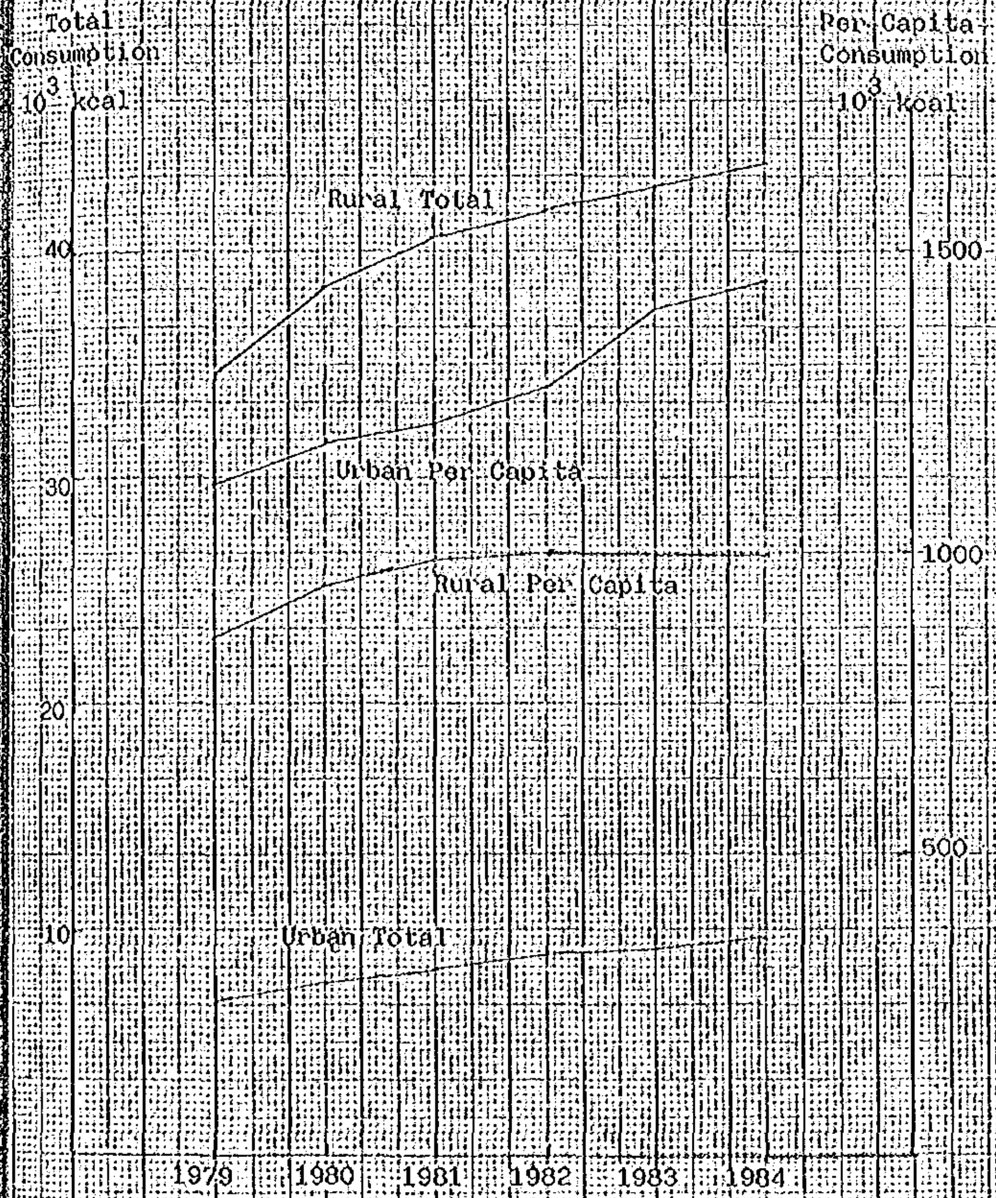


Figure I-1 : Total and Per Capita Consumption of Energy by Area

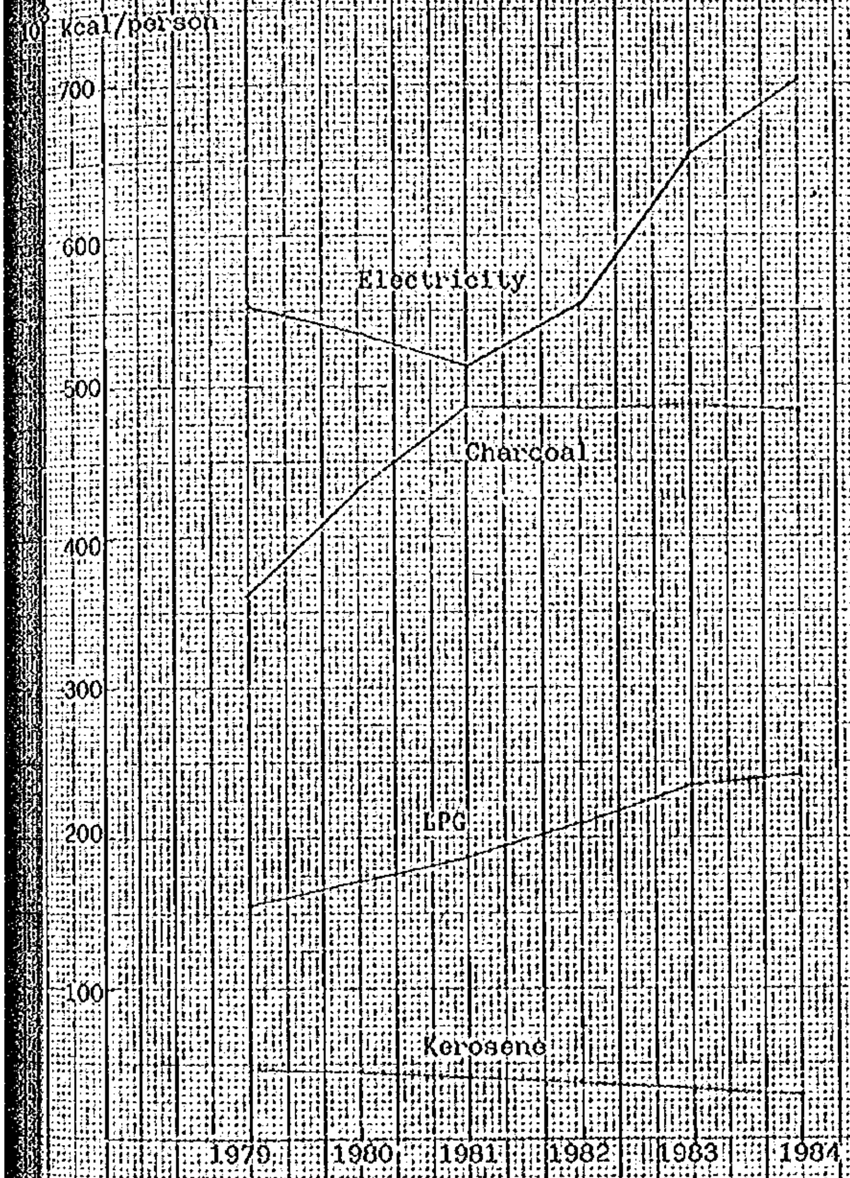


Figure 1-2 : Per Capita Energy Consumption by Type in Urban Household and Service Sector

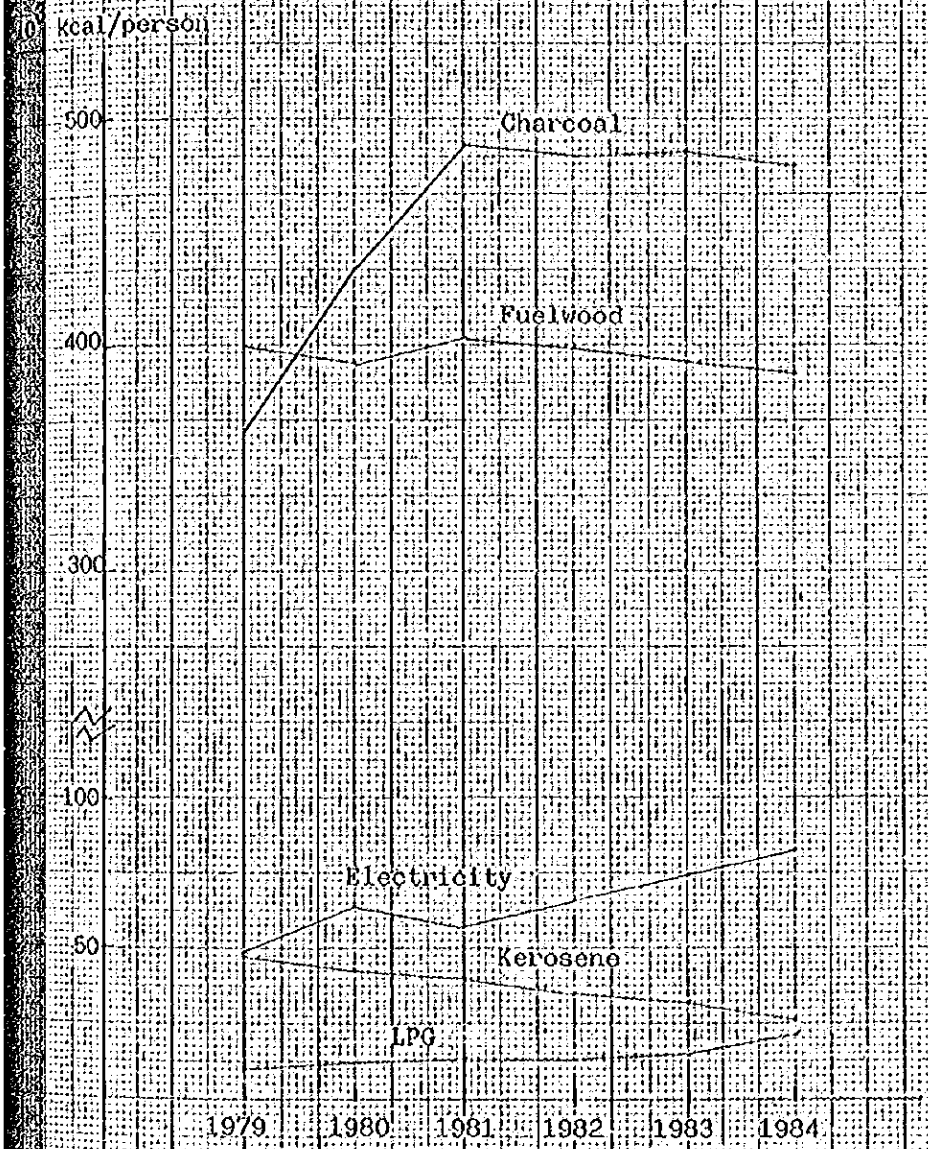


Figure I-3 Per Capita Energy Consumption by Type in Rural Household and Service Sector

As for electricity, the growth of consumption depend on the increase of electrified population and the increase of consumption per electrified person. Figure I-4 and I-5 show the commercial and residential electricity consumption per electrified person and the ratio of electrified population to total population in the two sectors. In the urban sector, the ratio of electrified population is rather high and its increase is slow, but consumption per electrified person increased in a high growth rate. On the contrary in the rural sector, the ratio of electrified population increased about twice from 1979 to 1984, but the consumption was stagnant for residential use and decreased for commercial use.

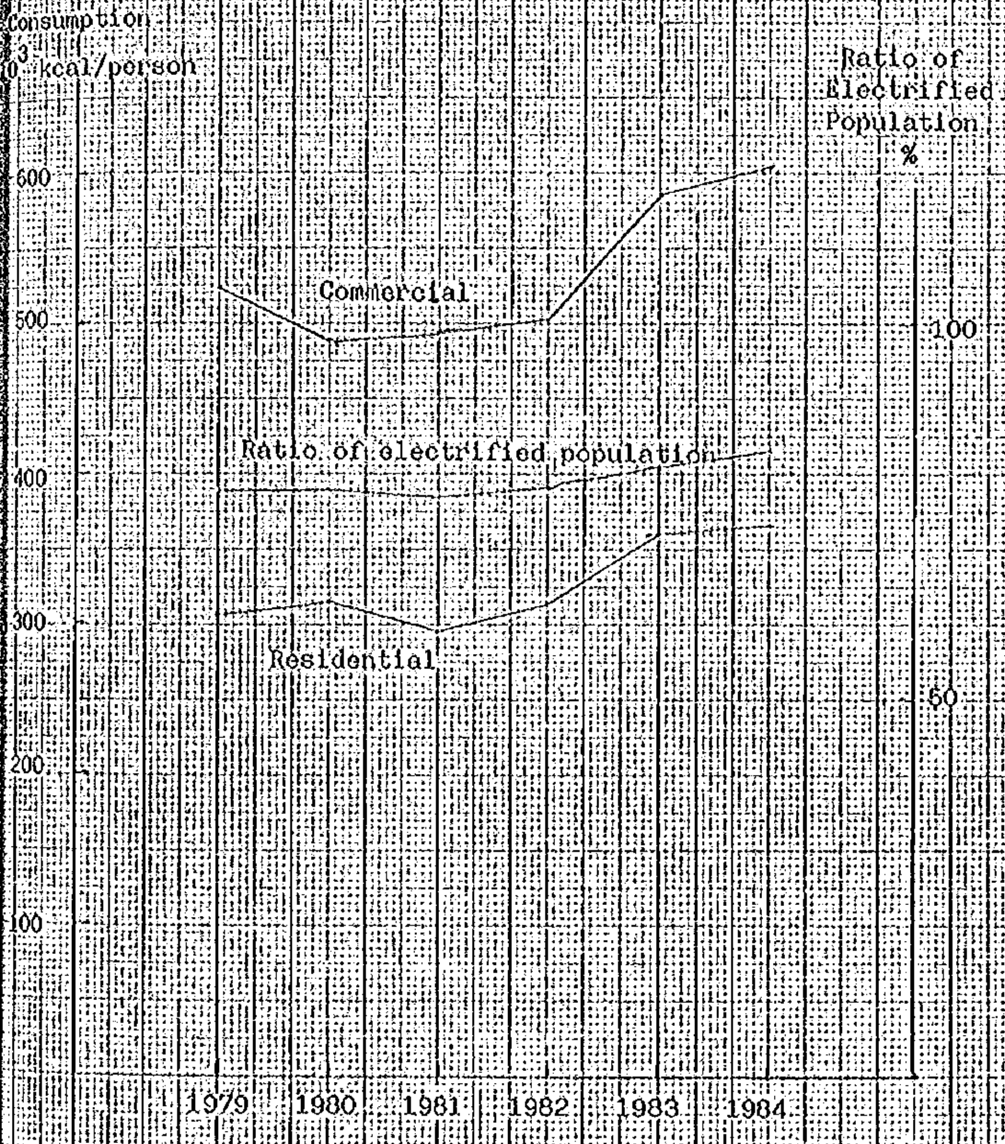
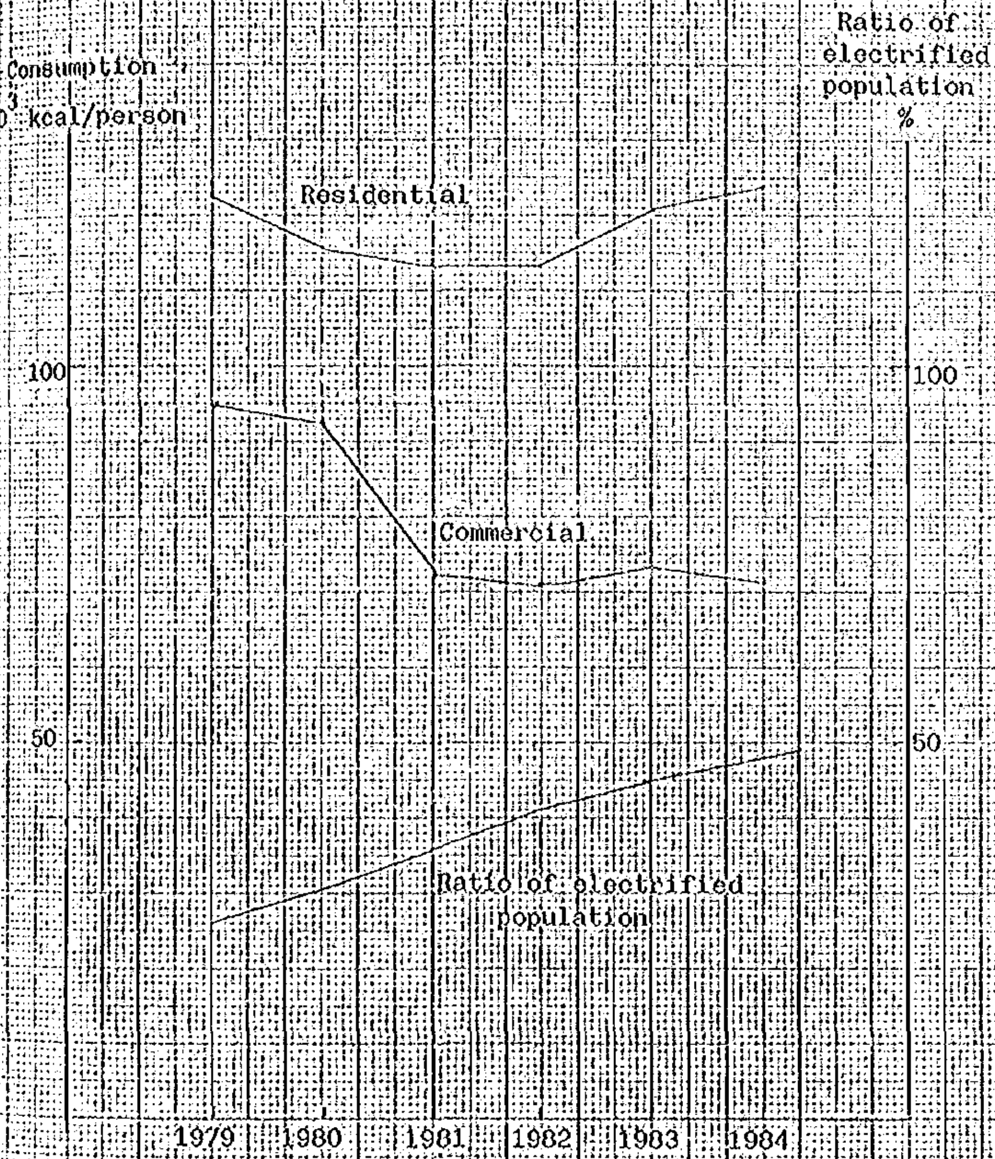


Figure I-4 Commercial and Residential Electricity Consumption per Electrified Person and Ratio of Electrified Population in Urban Sector



Figure, I-5 : Commercial and Residential Electricity Consumption per Electrified Person, and Ratio of Electrified Population in Rural Sector

2. Energy Demand functions

Regression analyses are conducted on the energy demand behaviours in this sector. Time series-cross section pooling data for the period 1979-1984, for the urban and the rural residential-service sectors are used.

1). Total Energy Demand

At first, we examine how the total energy demand is related to the growth of income. Two equations estimated are presented below.

$$\ln(TLHS/POP) = -0.51784 + 0.27720 \cdot \ln(GRPR/POP)$$
$$(-6.7) \qquad (8.2)$$
$$\bar{R}^2 = 0.858 \quad SD = 0.06$$

$$\ln(TLHS/POP) = -2.00162 + 1.14772 \cdot \ln(GRPR/POP)$$
$$(-5.8) \qquad (5.7)$$
$$-0.33633 \cdot DUMU \cdot \ln(GRPR/POP)$$
$$(-4.3)$$
$$\bar{R}^2 = 0.949 \quad SD = 0.04$$

where TLHS : Total energy consumption

POP : Population

GRPR : Real gross regional product

DUMU : Dumy variable Urban sector : 1.0

Rural sector : 0.0

The regression coefficient of the first equation is too low. That of the second equation which takes into consideration the difference of income elasticity of the two sectors, is improved. The income elasticity of total energy consumption is 0.81 for the urban sector and 1.15 for the rural sector according to the second equation. However, these results are not statistically significant enough.

To improve the results, the consept of useful energy is introduced.

To aggregate consumptions by type of energy, quantity of each type of energy is converted to caloric value based on its heat content. By doing this, we neglect differences in characteristics of each energy, such as conveniency, cleanness, efficiency etc. accompanied with the use. Generally, 1 kcal of modern energy is more valuable than 1 kcal of traditional energy, if the usefulness of energy is taken into consideration. In this sence, even if the total consumption is unchanged, when the shift from traditional energy to commercial energy takes place, the useful energy will increase [*1].

The following equation which considers this effect presents an improved result.

---

*1 The parameters, GROS-EFF, in the EMP model indicate the similar effects concerning the characteristics of using various types of energy. For cooking in urban and rural household and tertialy sector, GROS-EFF's are estimated as follows :

Biogas	0.40
Charcoal	0.27
Fuelwood	0.17
Husk	0.12
Kerosene	0.55
LPG	0.55
Electricity	1.00

$$\ln(TLHS/POP) = -3.12519 + 1.02179 \ln(GRPR/POP) + 1.51892 (TEHS/TLHS) \quad \text{------ (1)}$$
$$(-7.6) \qquad (8.6) \qquad (6.3)$$

$\bar{R}^2 = 0.971 \quad SD = 0.03$

where TEHS : Consumption of traditional energy

The second term of the right-hand side explains the effect of shift from traditional energy to modern energy on useful energy. In this equation, if no substitution occurs between these two types of energy, income elasticity of energy demand is 1.02 for both the urban and the rural sector. However, if the shift from traditional energy to modern energy takes place (TEHS/TLHS decreases) the total consumption (per capita) will decrease compared with the total consumption when the shift does not take place.

Per capita total energy demand are affected by not only per capita income but also price of energy. So energy demand function may be written as follows :

$$TLHS/POP = f(GRPR/POP, RPTL/CPI, ---)$$

where RPTL : Average retail price for total energy

CPI : Consumer price index

As for this type of energy demand function, any statistically significant estimation cannot be obtained. One of the relatively good results is shown below.

$$\ln(TLHS/POP) = -3.42234 + 1.10852 \cdot \ln(GRPR/POP)$$
$$(-3.3) \quad (3.6)$$
$$-0.04184 \cdot \ln(RPELP/CPI)$$
$$(-0.3)$$
$$+ 1.69198 \cdot TEHL/TLHS$$
$$(2.7)$$
$$\bar{R}^2 = 0.968 \quad SD = 0.03$$

where RPELP : Aggregated price index of electricity and LPG

In this equation, the parameter of real price of energy is not statistically significant.

From the estimated results which we have discussed, we should say that total energy consumption per capita cannot be explained by one equation which includes only a few factors as explanatary variables. This is because ` .· the energy demand is determined by some specific factors for each sector and total energy demand are determined as an aggregation of the demands.

2). Energy Demands by Types of Energy

Total energy demand are devided into the demands for traditional energy and the demand for modern energy.

As per capita modern energy demand function is estimated as follows :

$$\ln(MEHS/POP) = -5.32609 + 1.86277 \cdot \ln(GRPR/POP)$$
$$(-133.5) \quad (106.4)$$
$$-0.26340 \cdot \ln(RPELP/CPI) \text{ ------(2)}$$
$$(-4.4)$$
$$\bar{R}^2 = 0.999 \quad SD = 0.03$$

where MEHS : Consumption of modern energy

Per capita commercial energy consumption is determined by the real gross regional product per capita and the real retail prices of electricity and LPG. The income elasticity of demand is 1.86 and the price elasticity is -0.26.

As for the traditional energy, any per capita demand function cannot be estimated significantly. So, we estimated another type of function.

$$\ln(TEHS/MEHS) = \underset{(45.1)}{6.30626} - \underset{(-41.5)}{2.48946} \cdot \ln(GRPR/POP)$$

$$-\underset{(-4.3)}{2.38581} \cdot \ln(RPCH/RPELP) \text{ ------(3)}$$

$$\bar{R}^2 = 0.994 \quad SD = 0.11$$

In this equation, the ratio between consumption of traditional energy and that of modern energy is determined by the real gross regional product per capita and the relative price of charcoal to the price of modern energy (electricity and LPG). The parameter for GRPR/POP is minus. So, if GRPR/POP increase, the demand for traditional energy decreases relatively compared with that for modern energy.

For each type of energy (excluding kerosene and fuelwood), the specific energy demand functions are estimated.

<u>Charcoal (for the rural sector)</u>

$$\ln(CHHS/TEHS) = \underset{(-2.6)}{-11.9524} + \underset{(2.5)}{7.01592} \cdot \ln(GRPR/POP)$$

$$-\underset{(-2.2)}{0.11204} \cdot TIME \cdot \ln(GRPR/POP) \text{---(4)}$$

$$\bar{R}^2 = 0.800 \quad SD = 0.03$$

where CHHS : Consumption of charcoal

TIME : Time (1979 = 1.0)

The share of charcoal in the traditional energy will increase if (GRPR/POP) increases, but the rate of increase declines as time passes.

Fuelwood (for the rural sector)

$$\ln(FWHS/TEHS) = \underset{(1.5)}{0.69927} - \underset{(-3.1)}{0.85662} \cdot \ln(GRPR/POP) \text{---}(6)$$

$$\bar{R}^2 = 0.626 \quad SD = 0.04$$

where FWHS : Consumption of fuelwood

The share of fuelwood decreases as per capita income increases.

LPG

$$\ln(LPHS/POP) = \underset{(-31.2)}{-8.88669} + \underset{(24.9)}{2.62507} \cdot \ln(GRPR/POP)$$

$$\underset{(-0.6)}{-0.28501} \cdot DUMR \cdot \ln(RPLP/CPI) \text{---}(6)$$

$$\bar{R}^2 = 0.993 \quad SD = 0.12$$

where LPHS : Consumption of LPG

RPLP : Retail price of LPG

The per capita LPG consumption increases if GRPR/POP increases. And in the urban sector, it decreases if the real price of LPG increases.

Electricity

$$\ln(ELHS/ELPO) = \underset{(-66.9)}{-4.07210} + \underset{(46.9)}{1.38463} \cdot \ln(GRPR/POP)$$

$$\underset{(-5.1)}{-0.43553} \cdot \ln(RPEL/CPI) \text{ -----(7)}$$

$$\bar{R}^2 = 0.995 \quad SD = 0.05$$

where ELHS : Consumption of electricity

ELPO : Electrified population

As the realised demand for electricity is made by electrified population, the variable, electricity consumption per electrified person (ELHS/ELPO) is used. ELHS/ELPO increases if GRPR/POP increases, and decreases if real price of electricity (RPEL/CPI) increases.

Kerosene

$$\ln(KEHS/MEHS) = \underset{(-7.9)}{-4.99744} - \underset{(-6.1)}{1.39921} \cdot \ln(ELHS/POP)$$

$$\underset{(-2.0)}{+0.87760} \cdot DUMU \cdot \ln(ELHS/POP)$$

$$\underset{(1.0)}{+0.67831} \cdot DUMU$$

$$\bar{R}^2 = 0.991 \quad SD = 0.10$$

where KEHS : Consumption of kerosene

The share of kerosene in the total consumption of modern energy decreases as per capita electricity consumption increases.

Income elasticities of demand are calculated using the parameters estimated above (Table I-1). The income elasticity of total energy demand is 1.02. These for the modern energy and the traditional energy are 1.86 and -0.59 respectively. The negative elasticity for the traditional energy can be explained by that it is an inferior good. The elasticities for LPG are the highest among the modern energies, 3.23 for the urban sector and 3.61 for the rural sector. The income elasticity for electricity is 1.38. As for the traditional energy, the income elasticity for charcoal in the rural sector is positive (4.71). This is because the substitution from fuelwood to charcoal take place as the per capita income grows.

Own price elasticities of demand for some types of energy can be obtained from the estimates as shown in Table I-2.

Table I-1 : Income Elasticity of Demand

(per capita income elasticity)

	Income Elasticity		Equations Used
Modern Energy	1.86		(2)
Electricity	1.38		(6)
LPG	2.63		(5)
Kerosene	-		-
Traditional Energy	-0.59		(2), (3)
Charcoal	urban -0.63	rural* 4.71	(2),(3),(4)
Fuelwood	-	-1.48	(2),(3),(5)
Total	1.02		(1)

* Calculated at 1982.

Table I-2 : Own Price Elasticities of Demand

	Price Elasticity
Modern Energy	-0.26
Electricity	-0.44
LPG	-0.29 (rural)

3. Simulation Analysis

Using the equations estimated above, two econometric models for the urban and the rural household-service sectors are composed.

1). Model Equations

(1). Electricity

$$ELHS/\overline{ELPO} = f(\overline{GRPR}/\overline{POP}, \overline{RPEL}/\overline{CPI})$$

(2). Kerosene

$$KEHS/MEHS = f(ELHS/\overline{POP})$$

(3). LPG

$$LPHS/\overline{POP} = f(\overline{GRPR}/\overline{POP}, \overline{RPLP}/\overline{RPCH})$$

(4). Modern energy

$$MEHS = ELHS + KEHS + LPHS$$

(5). Tranditional energy

$$TEHS/MEHS = f(\overline{GRPR}/\overline{POP}, \overline{RPCH}/\overline{RPELP})$$

(6). Fuelwood (only for the rural sector)

$$FWHS/TEHS = f(\overline{GRPR}/\overline{POP})$$

(7). Charcoal

The rural sector

$$CHHS = TEHS - FWHS$$

The urban sector

CHHS = TEHS

(8). Total energy

TLHS = TEHS + MEHS

<u>Endogenous Variables</u>

MEHS	:	10^{12} kcal	: Consumption of modern energy
TEHS	:	10^{12} kcal	: Consumption of traditional energy
CHHS	:	10^{12} kcal	: Consumption of charcoal
FWHS	:	10^{12} kcal	: Consumption of fuelwood
LPHS	:	10^{12} kcal	: Consumption of LPG
ELHS	:	10^{12} kcal	: Consumption of electricity
KEHS	:	10^{12} kcal	: Consumption of kerosene
TLHS	:	10^{12} kcal	: Consumption of energy as a total

<u>Exogenous Variables</u>

$\overline{POP}$	:	10^{3}	: Total population of the rural or the urban area
$\overline{ELPO}$	:	10^{3}	: Electrified population of the rural or the urban area
$\overline{GRPR}$	:	10^{6} ฿	: Gross regional product at constant 1972 prices
$\overline{CPI}$	:	1980 = 1.0	: Consumer price index (Bangkok)
$\overline{RPEL}$	:	1980 = 1.0	: Price index of electricity (Bangkok)
$\overline{RPLP}$	:	1980 = 1.0	: Price index of LPG
$\overline{RPCH}$	:	1980 = 1.0	: Price index of charcoal

RPELP : 1980 = 1.0 : Aggregated price index of Electricity and LPG

2). Simulation

We perform simulation using the model for the period from 1985 to 2001. The exogenous variables for the reference case are set as follows :

Population : Annual growth rate (1984-2001)

The rural sector 1.0%

The urban sector 3.5%

Electrified Population : Ratio of electrified population on 2001 — Annual growth rate

The rural sector 80% (3.9%)

The urban sector 95% (4.3%)

Gross regional Product : Annual growth rate (1984-2001)

The rural sector 3.0%

(per capita GRP 2.0%)

The urban sector 5.5%

(per capita GRP 2.0%)

CPI : Annual increase rate (1984-2001)

The both sectors 3.0%

RPEL : Annual increase rate (1984-2001) 2.0%

RPLP : Annual increase rate (1984-2001) 2.0%

RPCH : Annual increase rate (1984-2001) 3.0%

Table I-3 shows the simulation results of the reference case.

Table I-3 : Simulation Results (The Reference Case)

10^{12} KCAL

	1979	1984	1986	1991	1986	2001	1979 -1984 %	1986 -1991 %	1991 -1996 %	1996 -2001 %
Rural Sector										
Modern Energy	4,226	5,770	6,397	8,446	11,433	15,712	6.4	5.7	6.2	6.6
Electricity	1,940	3,623	4,496	6,369	9,028	12,782	13.3	7.2	7.2	7.2
LPG	391	923	830	1,145	1,578	2,175	18.7	6.6	6.6	6.6
Kerosene	1,895	1,224	1,078	938	836	756	-8.4	-2.8	-2.3	-2.0
Traditional Energy	30,422	38,064	36,195	33,327	31,460	30,149	4.6	-1.6	-1.1	-0.8
Charcoal	14,497	21,050	21,026	20,485	20,314	20,328	7.7	-0.5	-0.2	-
Fuelwood	15,925	17,014	15,169	12,842	11,146	9,821	1.3	-3.3	-2.8	-2.5
Total	34,648	43,834	42,593	41,773	42,893	45,861	4.8	-0.4	0.5	1.3
Urban Sector										
Modern Energy	4,693	6,466	7,766	11,275	16,431	24,010	6.6	7.7	7.8	7.9
Electricity	3,436	4,671	5,403	7,778	11,196	16,116	6.3	7.6	7.6	7.6
LPG	963	1,607	2,171	3,315	5,062	7,729	10.8	8.8	8.8	8.8
Kerosene	294.0	188.0	191.4	181.5	172.7	164.8	-8.6	-1.1	-1.0	-0.9
Traditional Energy	2,243	3,201	2,837	2,889	2,953	3,027	7.4	0.4	0.4	0.5
Charcoal	2,243	3,201	2,837	2,889	2,953	3,027	7.4	0.4	0.4	0.5
Fuelwood	-	-	-	-	-	-	-	-	-	-
Total	6,936	9,667	10,603	14,164	19,384	27,037	6.9	6.0	6.5	6.9
Total										
Modern Energy	8,919	12,236	14,163	19,721	27,864	39,722	6.5	6.8	7.2	7.3
Electricity	5,376	8,294	9,899	14,147	20,219	28,898	9.1	7.4	7.4	7.4
LPG	1,354	2,530	3,001	4,460	6,640	9,904	13.3	8.2	8.3	8.3
Kerosene	2,189	1,412	1,269	1,120	1,009	921	-8.4	-2.5	-2.1	-1.8
Traditional Energy	32,665	41,265	39,032	36,216	34,419	33,176	4.8	-1.5	-1.0	-0.7
Charcoal	16,740	24,251	23,863	23,374	23,267	23,355	7.7	-0.4	-0.1	0.1
Fuelwood	15,925	17,014	15,169	12,842	11,146	9,821	1.3	-3.3	-2.8	-2.4
Total	41,584	53,501	53,196	55,937	62,277	72,898	5.2	1.0	2.2	3.2

In the rural household-service sector, the demand for modern energy increases 5.7% - 6.6% per annum in the period from 1986 to 2001. On the other hand, the demand for traditional energy decreases 0.8% - 1.6% per annum. As a results, the total demand in caloric value increases in a low growth rate (1986-2001 : 0.5%) in spite of the growth of per capita GRP (2.0%) and population (1.0%). This will imply that the increase of demand is coped with the shift from the traditional energy to the modern energy which increases the total useful energy.

In the urban household-service sector also, the demand for modern energy increase in a high rate (7.7% - 7.9% per annum), and the demand for traditional energy remain stable. However, the total energy demand increases in a higher growth rate than in the rural sector (6.0% - 6.9% per annum) because in the urban sector the share of traditional energy in the total energy is already small. And this will imply that in this sector, the increase of the useful energy caused by the shift from the traditional energy to the modern energy is relatively small.

In the household-service sector as a total, the demand for modern energy increase 6.8% - 7.3% per annum. The demand for traditional energy decreases from the present level. Especially the demand for fuelwood decreases rapidly and it will be about a half of that in 1986.

Finally, an analysis on the effects by changes of energy prices and income on the energy demand by type is performed. Two simulation cases are set based on the reference case.

Low Price Case : Price of electricity and LPG increase 1.0% per annum in the simulation period, compared with 2.0% per annum for Reference Case. The prices of electricity and LPG for Low Price Case are 13% lower than those for Reference Case in 2001.

High GRP Case : GRP increases 4% per annum in the rural sector and 6.5% per annum in the urban sector, compared with 3% and 5.5% respectively for the Reference Case. The per capita GRPs for High GRP Case are 18% higher than those for Reference Case in 2001.

Other exogenous variables are unchanged from those for the Reference Case. The model is solved up to 2001 for the two cases.

Table I-4 and I-5 present the results by the two cases, and Figure I-6 and I-7 show effects by changes of prices and per capita GRP on demands of energy by type.

e I-4 : Simulation Results (Low Price Case)

10^{12} KCAL

	1986	1991	1986	2001	1986 -1991 %	1991 -1996 %	1996 -2001 %
al Sector							
ern Energy	6,433	8,646	11,941	16,758	6.1	6.7	7.0
lectricity	4,535	6,563	9,500	13,750	7.7	7.7	7.7
PG	835	1,167	1,632	2,282	6.9	6.9	6.9
erosene	1,071	920	812	728	-3.0	-2.5	-2.2
aditional Energy	34,729	28,939	24,781	21,563	-3.6	-3.1	-2.7
harcoal	20,174	17,787	16,001	14,539	-2.5	-2.1	-1.9
uelwood	14,555	11,151	8,780	7,024	-5.2	-4.7	-4.4
Total	41,163	37,585	38,722	38,321	-1.8	-0.5	0.9
an Sector							
dern Energy	7,810	11,503	17,009	25,212	8.1	8.1	8.2
lectricity	5,450	8,015	11,787	17,335	8.0	8.0	8.0
PG	2,171	3,315	5,062	7,729	8.8	8.8	8.8
erosene	188.9	173.2	159.5	147.2	-1.7	-1.6	-1.6
aditional Energy	2,722	2,501	2,306	2,132	-1.7	-1.6	-1.6
harcoal	2,722	2,501	2,306	2,132	-1.7	-1.6	-1.6
uelwood	-	-	-	-	-	-	-
Total	10,532	14,004	19,315	27,343	5.9	6.6	7.2
al							
dern Energy	24,243	20,149	28,950	41,970	7.2	7.5	7.7
lectricity	9,985	14,578	21,287	31,085	7.9	7.9	7.9
PG	3,006	4,482	6,694	10,011	8.3	8.4	8.4
erosene	1,260	1,093	972	875	-2.8	-2.3	-2.0
aditional Energy	37,451	31,440	27,087	23,695	-3.4	-2.9	-2.6
harcoal	22,896	20,288	18,307	16,671	-2.4	-2.0	-1.9
uelwood	14,555	11,151	8,780	7,024	-5.2	-4.7	-4.4
Total	51,695	51,589	56,037	65,664	-	1.7	3.2

e I-5 : Simulation Results (High GRP Case)

10^{12} KCAL

	1986	1991	1986	2001	1986 -1991 %	1991 -1996 %	1996 -2001 %
l Sector							
ern Energy	6,545	9,258	13,520	20,097	7.2	7.9	8.3
ectricity	4,618	6,995	10,594	16,047	8.7	8.7	8.7
G	874	1,367	2,139	3,348	9.4	9.4	9.4
rosene	1,063	901	790	704	-3.2	-2.6	-2.3
ditional Energy	35,295	30,867	27,874	25,620	-2.6	-2.0	-1.7
arcoal	20,746	19,642	18,932	18,369	-1.1	-0.7	-0.6
elwood	14,549	11,225	8,942	7,250	-5.1	-4.4	-4.1
Total	41,840	40,125	41,394	45,717	0.8	0.6	2.0
n Sector							
dern Energy	8,014	12,631	20,059	32,033	9.5	9.7	9.8
ectricity	5,546	8,523	13,096	20,123	9.0	9.0	9.0
G	2,282	3,943	6,814	11,776	11.6	11.6	11.6
erosene	186.4	166.0	148.9	134.4	-2.3	-2.1	-2.0
aditional Energy	2,794	2,746	2,720	2,709	-0.3	-0.2	-0.1
harcoal	2,794	2,746	2,720	2,709	-0.3	-0.2	-0.1
uelwood	-	-	-	-	-	-	-
Total	10,808	15,378	22,779	34,742	7.3	8.2	8.8
al							
dern Energy	14,559	21,889	33,579	52,130	8.5	8.9	9.2
lectricity	10,164	15,518	23,690	36,170	8.8	8.8	8.8
G	3,156	5,310	8,953	15,126	11.0	11.0	11.1
erosene	1,249	1,067	939	838	-3.1	-2.5	-2.3
aditional Energy	38,089	33,613	30,594	28,329	-2.5	-1.9	-1.5
harcoal	23,540	22,388	21,652	21,078	-1.0	-0.7	-0.5
uelwood	17,343	11,225	8,942	7,252	8.3	-4.4	-4.1
Total	52,648	55,503	64,173	80,459	5.4	2.9	4.6

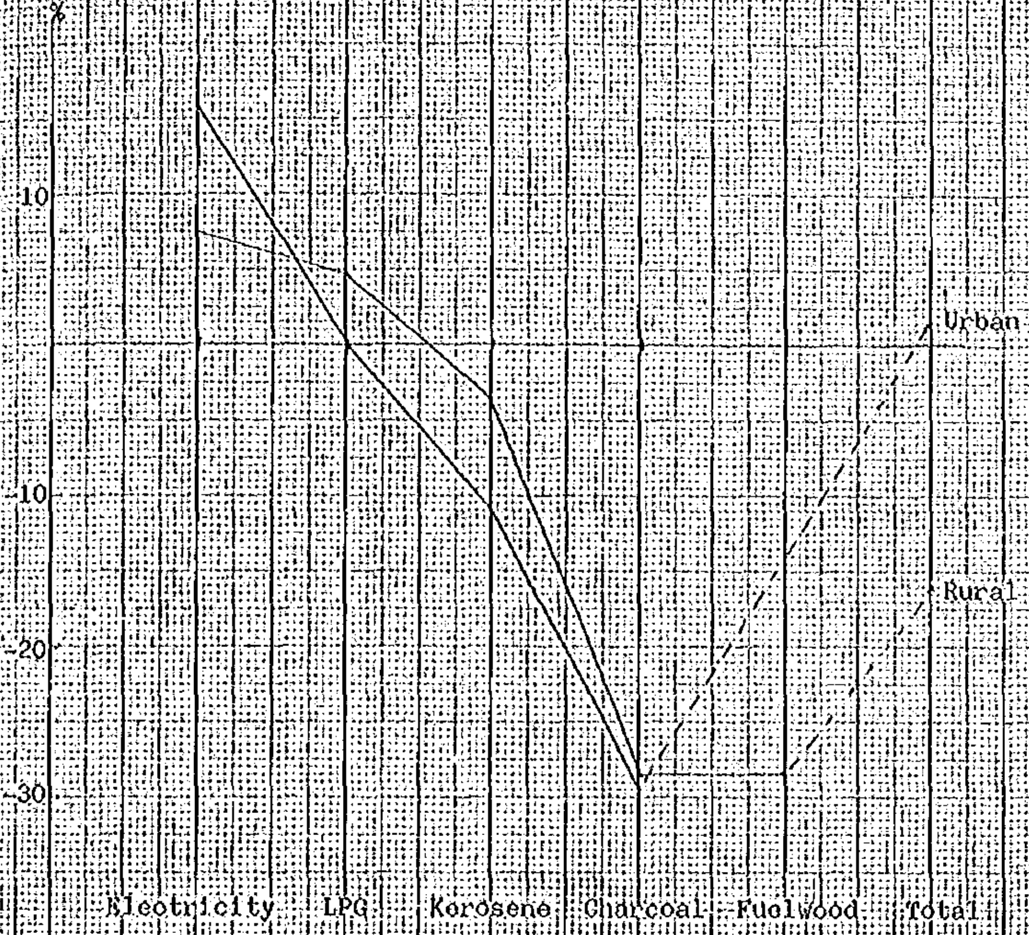


Figure I-6 : Effects by Price Changes, Differences between Demands by Low Price Case and Reference Case in 2001

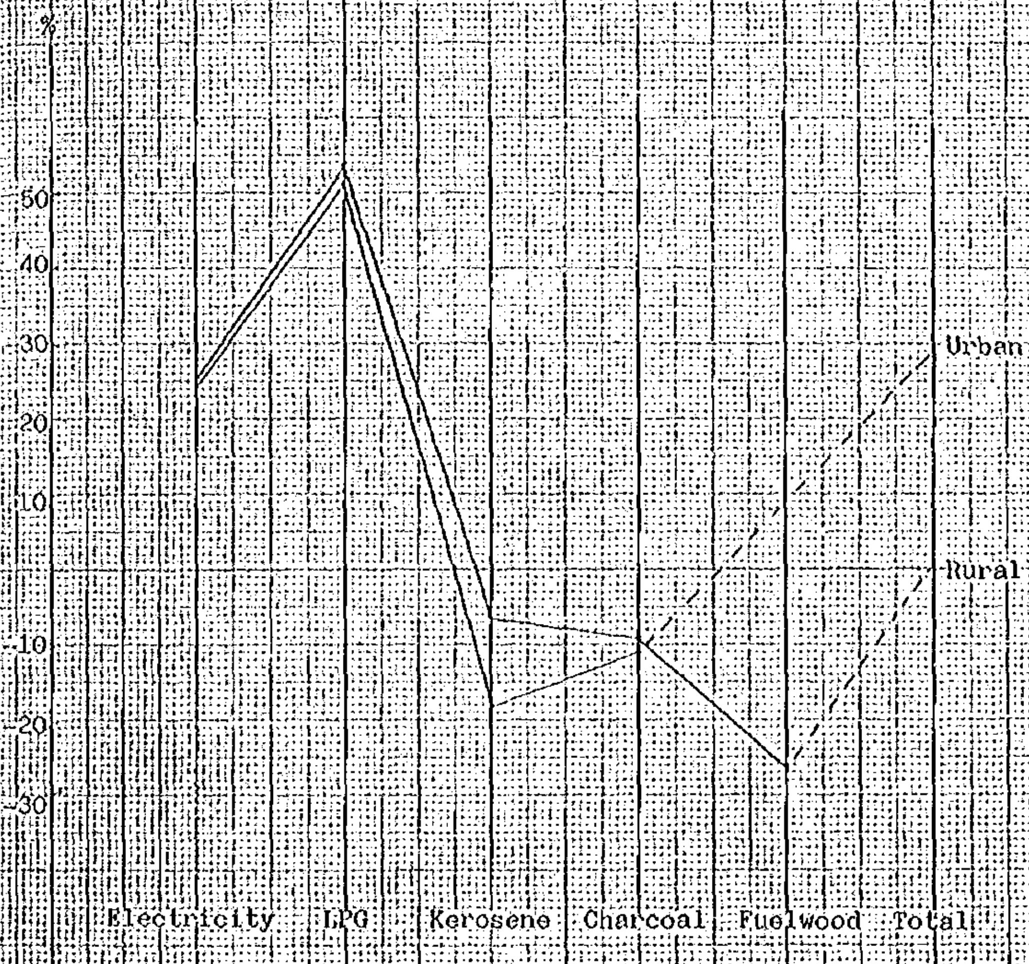


Figure I-7 : Effects by Changes of Per Capita Income, Differences between Demands by High GRP Case and Reference Case

As Figure I-6 shows, if prices of electricity and LPG declines the demand for electricity and LPG (for the rural sector) increase, but the demands for the other energies decrease through the substitution effects caused by the changes of relative prices. And, the total demand increase in only 1.0% for urban sector, and decrease 16% for the rural sector. The decreases of demands for the traditional energy may be overestimated. However, it is obvious that the shift from the traditional energy to the modern energy has the effect to suppress the total energy demand.

As for the effects by the changes of per capita GRP, similar effects can be seen as for Low Price Case. As per capita GRP increases, the shift from the traditional energy to the modern energy takes place and the demands for the traditional energy decrease. However, the increase in per capita GRP induces higher demands as a total, and especially for LPG than those by Low Price Case. And it should be noted than income effects on demand are positive for electricity and LPG only. For the other energies the demands decrease as per capita GRP increases.

Conclusions

This study will be useful for the understanding of the energy demand behaviour by the household-service sector, and will provide some preliminary informations to construct more acculate models. The model constructed in this study contains some points to be improved.

1). Data, especially on the energy demands by type of energy and by sector, were estimated based on very simple assumptions, and may possibly be re-estimated with more accuracy.

2). The structure of the model and the specifications of the equations can be examined based on the simulations mentioned above, and can be improved.

3). For forecasting, more informations other than the data (and the model) actually used are needed, i.e., informations on the future energy pricing policy, rural electrification, and economic growth rate in the future (for the exogenous variables), and on the energy consumption behaviour by this sector.

ANNEX Estimation of Energy Demand Data

Except the electricity consumption, energy consumption data are estimated for the urban and the rural household and service sectors, under the assumptions as follows :

Fuelwood : No consumption in the urban sector. Total consumption in this country is allocated to the rural area according to the share of this sector in 1977 (EMP study).

Charcoal : Total consumption in this country is allocated to the urban and rural sectors based on the shares of population in the two sectors.

Kerosene : Consumption in the household and service sectors by NEA statistics is allocated to the two sectors based on their population.

LPG : Consumption in the household and service sectors by NEA statistics is allocated to the two sectors, based on the shares of total LPG consumption by the two areas.

The consumptions of the other energies are neglected, because their quantities are very small.

Table 1 : Energy Consumption in Rural Household and Service Sector

10^{12} KCAL

	1979	1980	1981	1982	1983	1984
Fuel-Wood	15,925	15,925	16,392	16,794	16,835	17,014
Charcoal	14,497	17,657	20,152	20,311	20,899	21,050
Kerosene	1,896	1,776	1,681	1,495	1,371	1,224
LPG	391	447	502	531	596	923
Electricity	1,940	2,254	2,359	2,731	3,197	3,623
Total	34,648	38,359	40,584	41,862	42,898	43,834
Population ($x10^3$)	39,913	40,560	41,233	42,030	42,977	43,923

Table 2 : Energy Consumption in Urban Household and Service Sector

10^{12} KCAL

	1979	1980	1981	1982	1983	1984
Charcoal	2,243	2,779	3,226	3,306	3,150	3,201
Kerosene	294	281	269	243	207	188
LPG	963	1,099	1,236	1,429	1,515	1,607
Electricity	3,436	3,437	3,395	3,786	4,237	4,671
Total	6,936	7,596	8,126	8,764	9,109	9,667
Population ($x10^3$)	6,201	6,401	6,625	6,817	6,456	6,660

Table 3 : Per Capita Energy Consumption in Rural Household and Service Sector

10^3 KCAL/PERSON

	1979	1980	1981	1982	1983	1984
Fuelwood	399.0	392.6	403.9	399.6	391.7	387.4
Charcoal	363.2	435.3	488.7	483.3	486.3	479.2
Kerosene	47.5	43.8	40.8	35.6	31.9	27.9
LPG	9.8	12.8	12.2	12.6	13.9	21.0
Electricity	48.6	64.4	57.2	65.0	74.4	82.5
Total	868.1	945.7	984.3	996.0	998.2	998.0

Table 4 : Per Capita Energy Consumption in Urban Household and Service Sector

10^3 KCAL/PERSON

	1979	1980	1981	1982	1983	1984
Charcoal	361.7	434.2	486.9	485.0	487.9	480.6
Kerosene	47.4	44.0	40.6	35.6	32.1	28.2
LPG	155.3	171.7	186.6	209.6	234.7	241.3
Electricity	554.1	536.9	512.5	555.4	656.3	701.4
Total	1,118.5	1,186.7	1,226.6	1,285.6	1,410.9	1,451.5

II. Fuel Consumption by Vehicles

The transportation sector consumes more than 90% of gasoline and more than 50% of diesel oil consumed in this country. The vehicles take the predominant role in the transportation. This paper is aimed to conduct a preliminary analysis on the mechanisms which determine energy consumption by vehicles. Time series data on fuel consumption by type of energy and by type of vehicles are not available. And as it is difficult to estimate these data based on published data, only the existing data are used in this analysis. And some hypothetical structure are set about the fuel demand behaviour and tested by the methods of econometrics.

1. Fuel Consumption and its Substitution Possibility

In the last several years, the consumption of gasoline decreased relatively and those of diesel oil and LPG increased substantially. This structural change is mainly caused by the increase of diesel-fueled trucks, and the increase of LPG consumption by small trucks and passenger cars. The principal purpose of this analysis is to reveal the mechanisms which determine the demands for these fuels.

The mechanisms of fuel substitution can be devided into two types in the economic sence.

1). In the first type as between gasoline and diesel oil, substitution of fuel is possible only at the time of purchase of vehicles. The users cannot change fuel type unless they change their cars. This type of substitution takes place in the long-run, in the sence that the substitution is possible by the investment (purchase of cars) by users, and also in some cases by the investment by the manufactures.

2). In the second type as between gasoline and LPG, the substitution is possible by some modification of car. This type of substitution takes place in the short-run corresponding to the fuel price changes, because the cost of modification is relatively small.

The mechanisms which determine the demands for the three major fuels can be formalized as follows :

Diesel Oil

Large trucks and buses use diesel oil exclusively, but for small trucks and buses, diesel oil is substitutable to gasoline (or LPG). In this analysis, trucks, passenger cars and motorcycles are considered explicitly as consumers. And passenger cars are assumed to use only gasoline or LPG. For the consumption of diesel oil, a simple model can be considered as follows :

TRUCK = f(GDPR, ---) ------(1)

where TRUCK : Total number of trucks

GDPR : Real gross domestic product

TRUCK = LTRUCK + STRUCK ------(2)

where LTRUCK : Number of large trucks

STRUCK : Number of small trucks

STRUCK = DSTRUCK + GSTRUCK ------(3)

where DSTRUCK : Number of diesel-fueled small trucks

GSTRUCK : Number of gasoline (or LPG)-fueled small trucks

$$DSTRUCK = DSTRUCK_{-1} + PDSTRUCK - PDSTRUCK_{-i} \quad \text{-----(4)}$$

where PDSTRUCK : Number of purchase of diesel-fueled small trucks

and suffix (-1, -i) means lags (years).

$$PDSTRUCK/PSTRUCK = f(RPDL/RPGA, ---) \quad \text{-----(5)}$$

where RPDL : Retail price of diesel oil

RPGA : Retail price of gasoline

PSTRUCK : Number of purchase of small trucks

$$DLVE = f(LTRUCK, DSTRUCK, RPDL/PGDP, ---) \quad \text{-----(6)}$$

where DLVE : Consumption of diesel oil by vehicles

PGDP : GDP deflator

The total number of trucks is determined by GDP and the other factors, for example fuel prices (equation (1)). Trucks are devided into large and small trucks (2). And for small trucks, the number of purchases of diesel-fueled small trucks to the total number of purchases of small trucks is determined by fuel prices (5). The number of diesel-fueled small trucks is determined based on the number in the previous year and the number of purchases and abolitions of them in this year (4). And finally the demand for diesel oil is determined by the number of large trucks and diesel-fueled small trucks, and real prices of diesel oil which affect the fuel consumption per one vehicle. In this model the substitution between diesel oil and gasoline takes place through the change of the share of diesel-fueled small tracks in small trucks as a total. Here the substitution between gasoline and diesel oil through the modification of vehicles (for example by changing engines) is neglected.

<u>Gasoline and LPG</u>

Passenger cars use gasoline predominantly, and some of small trucks use gasoline. Here the two types of substitution are considered. Especially for small trucks the substitution between diesel oil and gasoline or LPG is possible (the first type of substitution), and for gasoline-fueled vehicles the substitution from gasoline to LPG is possible (the second type of substitution).

PASCAR = f(GDPR, ---) ------(1)

where PASCAR : Number of passenger cars

GPPAS = f(PASCAR, GSTRUCK, RPGP/RPDL, ---) ---(2)

where GPPAS : Consumption of gasoline and LPG by vehicles

GSTRUCK : Number of gasoline fueled small trucks

GAPAS/GPPAS = f(RPGA/RPLP, ---) ------(3)

where GAPAS : Consumption of gasoline by vehicles

RPLP : Retail price of LPG

LPPAS = GPPAS - GAPAS ------(4)

where LPPAS : Consumption of LPG by vehicles

MOTOCY = f(GDPR, ---)

where MOTOCY : Number of motorcycles

GAMOTC = f(RPGA/PGDP, MOTOCY)

where GAMOTC : Consumption of gasoline by motorcycles

The total consumption of gasoline and LPG is determined by the number of passenger cars and gasoline-fueled small trucks (equation (2)). In this equation, the substitution between gasoline and diesel oil takes place through the change of number of gasoline-fueled small trucks (connected with the change of number of diesel-fueled small trucks). And the substitution between gasoline and LPG takes place depending on the relative price of gasoline to LPG (3). For motorcycles, the demand for fuel is determined by two equations (5), (6).

2. Estimation of Fuel Demand Functions

Fuel demand functions discussed above are estimated with a small modification because of the lack of data, using the time series data for the period 1974-1984. Data on fuel consumptions by type are estimated based on simple assumptions *2. The maximum retail prices are used as retail prices of fuels. Number of diesel-fueled and gasoline-fueled small trucks are estimated on the data of purchases of these two types of trucks assuming a fixed lifetime (10 years). Data for the other variables are supplied by the EMP project.

Diesel Oil

The diesel oil demand function for vehicles is estimated as follows. As shown in Figure II-1, this equation explains well the actual movement of the demand both in the short-run and the long-run.

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*2 The diesel oil consumption by railway and the gasoline consumption by motorcycles are estimated based on the number of motorcycles, passenger-kilometers and freight-kilometers, etc. The consumptions of gasoline and LPG by vehicles excluding motorcycles are calculated by extracting these values form the consumptions by the transportation and communication sector.

$$DLVE = -2739.10 + 43.4959\ TRUCK + 15.1248\ DSTRUCK$$
$$(-0.7) \quad (6.0)$$
$$-0.39492\ (RPDL_{-1}/PGDP_{-1} - 1)\ DLVE$$
$$(-1.5)$$
$$\bar{R}^2 = 0.833 \quad SD = 2072.4 \quad DW = 1.76$$

Here, the prices are standardized as that for 1980 = 1.0. As the data on the number of large truck are not available, the total number of trucks (TRUCK) is used instead of it. The parameter for GSTRUCK in the equation for GPPAS below is used as that for DSTRUCK, assuming that fuel consumption by a gasoline-fueled small truck is equal to that by a diesel-fueled small truck.

As the estimated equation shows, the real price of diesel oil in the previous year explains well the price effect on demand. The equation can be rewritten as follows.

$$DLVE = (-2739.10 + 43.4959\ TRUCK + 15.1248 \cdot DSTRUCK)$$
$$/(1 + 0.39492 \cdot (RPDL_{-1}/PGDP_{-1} - 1))$$

As the denominator of the left-hand side of the equation becomes 1.0 at the year 1981, around this year the parameters for TRUCK and DSTRUCK show fuel consumption by one vehicle of each type. So if we assume the number of large trucks is 30% of the total number of trucks, the parameter of TRUCK 43.4959 multiplied by 1/0.3 (=145.0) can be considered as the parameter for large trucks. According to the results, at the year 1981 the increase of one large truck or one small truck increases 145.0×10^6 kcal or 15.1×10^6 kcal of diesel oil demand respectively.

As for the number of diesel fueled small trucks, a function which explains the number of purchase of diesel-fueled small trucks is estimated as follows (Figure II-2).

$$\log (PDSTRU/(PDSTRU + PGSTRU))$$

$$= \underset{(-9.9)}{-3.82312} + \underset{(7.4)}{0.91408} \; (RPGA + RPGA_{-1} + RPGA_{-2} - RPDL$$

$$- RPDL_{-1} - RPDL_{-2})/(PGDP + PGDP_{-1} + PGDP_{-2})$$

$\bar{R}^2 = 0.870 \quad SD = 0.33 \quad DW = 1.82$

For this equation, retail prices presented in Baht/litre are used. This equation shows that the share of purchases of diesel-fueled small trucks in the total purchases of small trucks is determined by the difference between the prices of gasoline and diesel-oil for the present and previous two years.

Gasoline and LPG

The demand function for the sum of gasoline and LPG and the share function for gasoline are estimated. Figure II-3 and II-4 show the comparison between the estimated values and the actual values.

$$GPPAS = \underset{(-0.1)}{2868.72} + \underset{(5.9)}{12.6775} \cdot PASCAR + \underset{(3.2)}{15.1248} \cdot GSTRUCK$$

$$- \underset{(-7.9)}{0.67117} \, (RPGA_{-1}/PGDP_{-1} - 1) \;\; GPPAS$$

$\bar{R}^2 = 0.892 \quad SD = 350.0 \quad DW = 2.74$

The function is estimated in the same specification as in the first equation.

For this equation, the real price of gasoline is used because the share of LPG consumption in the total consumption is small in the sample period. And that of the previous year gives a good regression result.

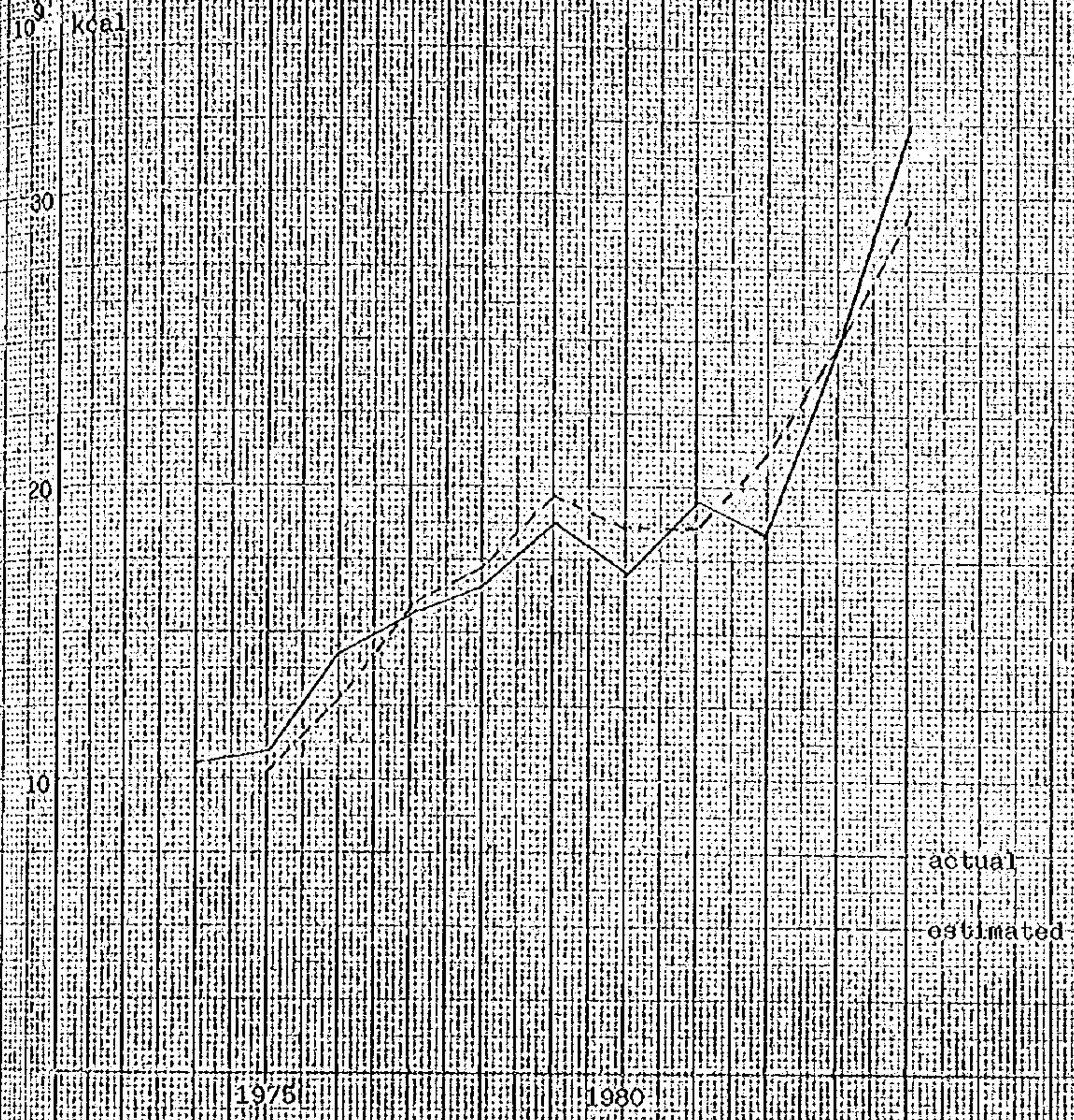

Figure II-1 Actual and Estimated Values of Diesel Oil Consumption of Vehicles

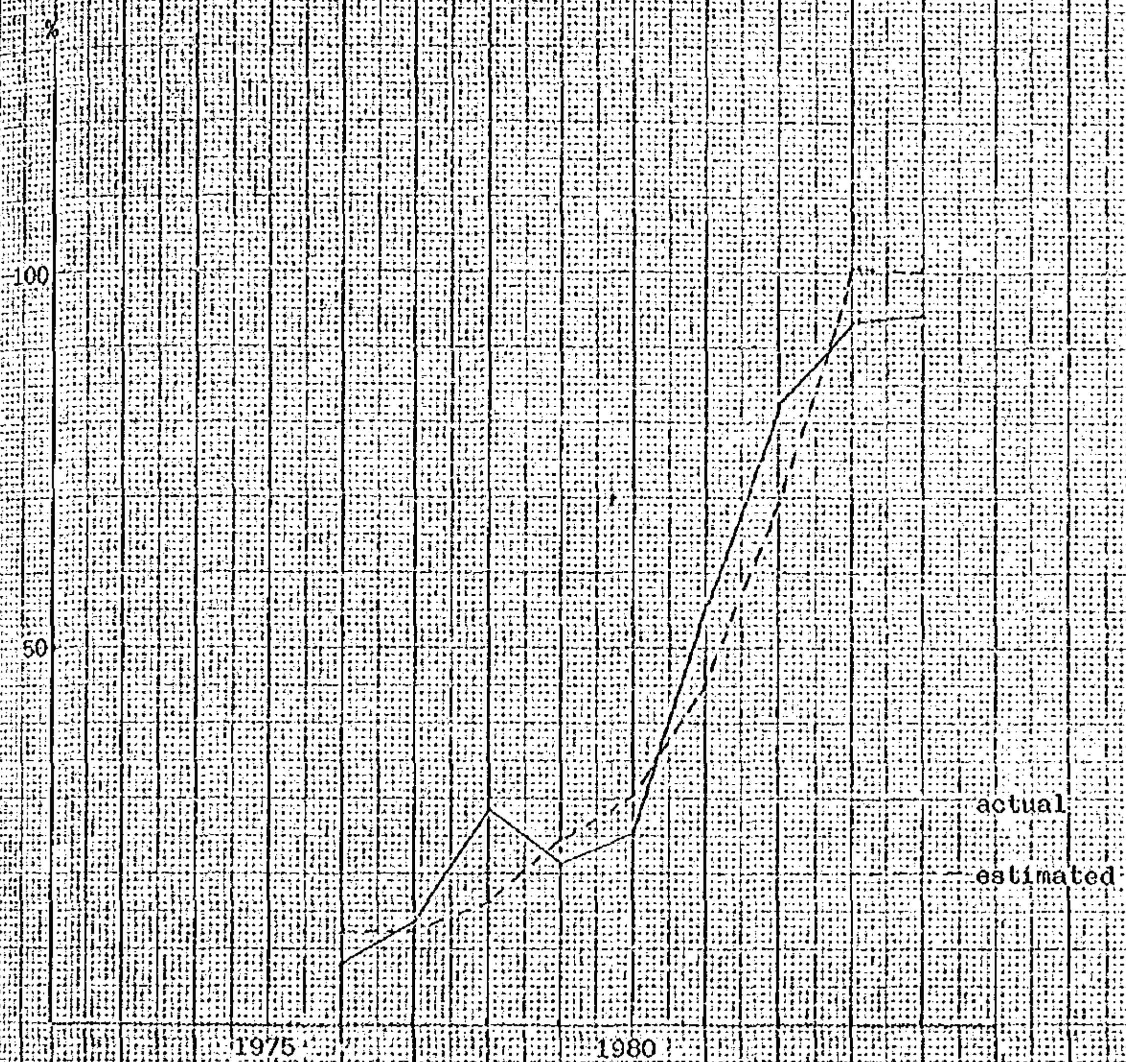

Figure II-2 : Actual and Estimated Values of the Share of Purchases of Diesel-Fueled Small Trucks

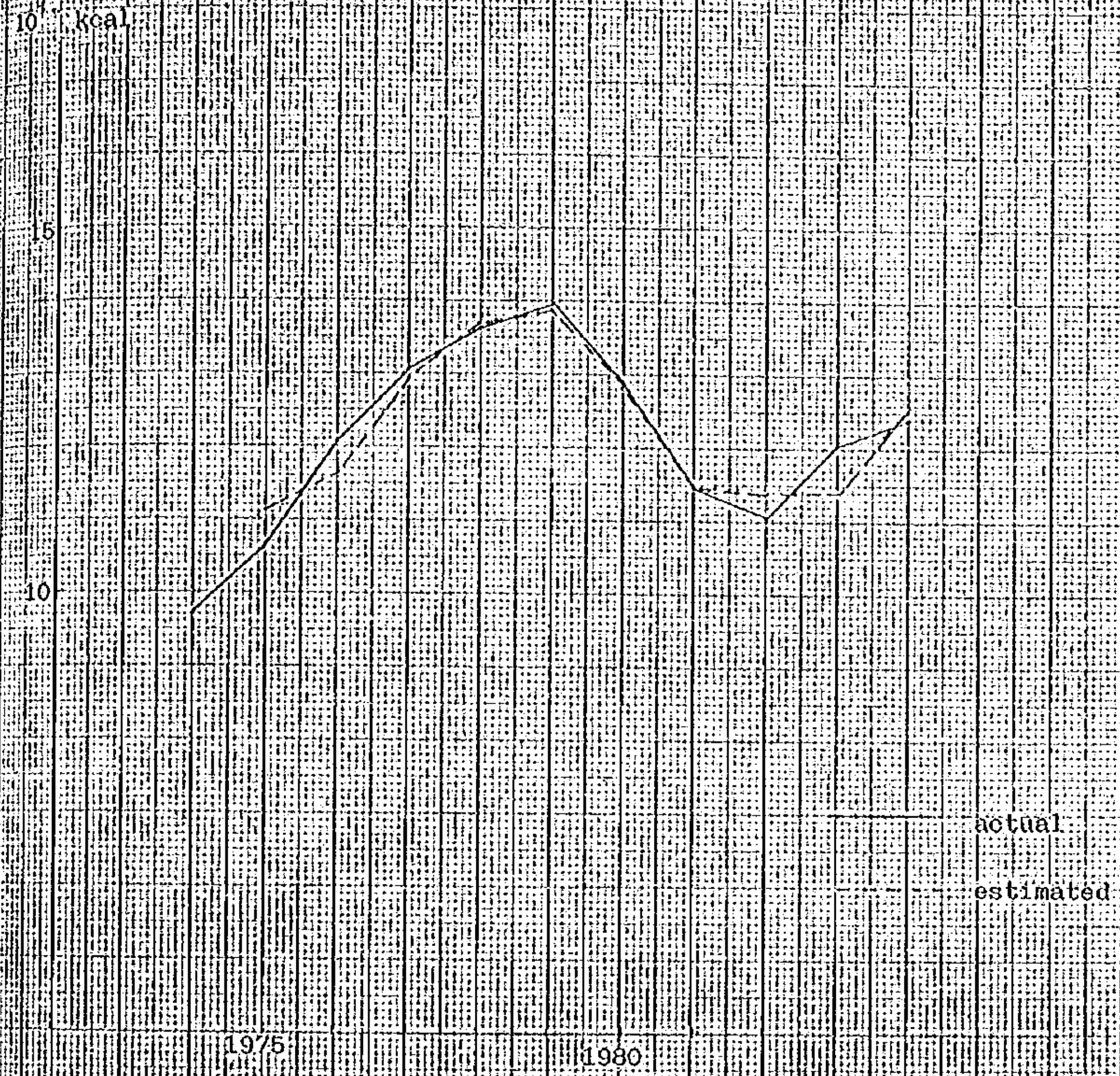

Figure TI-3   Actual and Estimated Values of Gasoline and
LPG Consumption by Vehicles

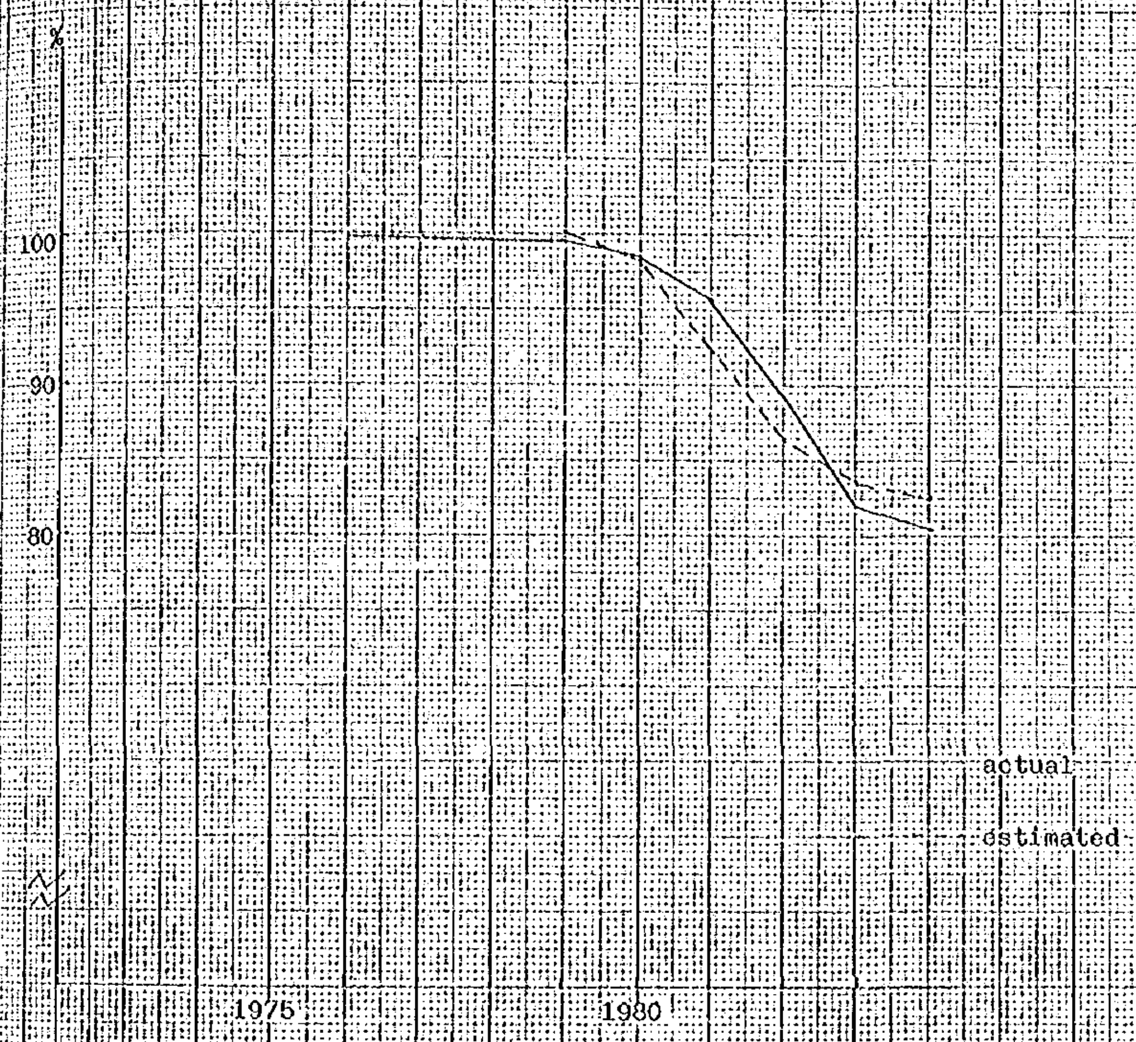

Figure II-4 : Actual and Estimated Values of the Share of Gasoline Consumption

According to the result, the increase of one passenger car increase 12.7 x 10^6 kcal of gasoline or LPG demand, and the increase of one gasoline-fueled small truck increase 15.1 x 10^6 kcal of gasoline or LPG demand.

A share function of gasoline in the sum of gasoline and LPG is estimated as follows :

$$\log(GAPAS/GPPAS) = \underset{(3.0)}{0.10945} - \underset{(-6.2)}{0.05436} \cdot (RPGA + RPGA_{-1} + RPGA_{-2} + RPGA_{-3} - RPLP - RPLP_{-1} - RPLP_{-2} - RPLP_{-3}) / (PGDP + PGDP_{-1} + PGDP_{-2} + PGDP_{-3})$$

$\bar{R}^2 = 0.881$ SD = 0.03 DW = 1.14

The share is determined by the difference between the prices of gasoline and LPG for the present and previous three years.

3. Analysis Using the Estimated Results

Using the four equations which are estimated above and some equations from EMP Model, a simple econometric model can be build.

1). Model

Equations

(1) Number of trucks

$$TRUCK = \underset{(-12.2)}{-218.79} + \underset{(32.7)}{0.99237} \cdot \overline{GDPR}$$

$\bar{R}^2 = 0.987$ SD = 18.8 DW = 1.33

(2) Number of passenger cars

$$PASCAR = -46.7132 + 0.71245 \cdot \overline{GDPR}$$
$$(-1.8) \qquad (15.9)$$

$$\overline{R}^2 = 0.947 \quad SD = 27.9 \quad DW = 0.48$$

(3) Number of motorcycles

$$MOTOCY = -833.717 + 2.91026 \cdot \overline{GDPR}$$
$$(-4.94) \qquad (10.23)$$

$$\overline{R}^2 = 0.881 \quad SD = 177.4 \quad DW = 0.342$$

(4) Share of purchases of diesel-fueled small trucks in purchases of small trucks

$$\ln SPDSTRU = -3.82312 + 0.91408 \cdot (\overline{RPGA} + \overline{RPGA}$$
$$(-9.9) \qquad (7.4)$$
$$+ \overline{RPGA}_{-2} - \overline{RPDL} - \overline{RPDL}_{-1} - \overline{RPDL}_{-2})$$
$$/(\overline{PGDP} + \overline{PGDP}_{-1} + \overline{PGDP}_{-2})$$

$$\overline{R}^2 = 0.870 \quad SD = 0.33 \quad DW = 1.82$$

(5) Purchases of diesel-fueled small trucks

$$PDSTRUCK = SPDSTRU \quad STRUCK$$

(6) Number of diesel-fueled small trucks

$$DSTRUCK = DSTRUCK_{-1} + PDSTRUCK - PDSTRUCK_{-10}$$

(7) Purchases of gasoline-fueled small trucks

$$PGSTRUCK = \overline{PSTRUCK} - PDSTRUCK$$

(8) Number of gasoline-fueled small trucks

$$GSTRUCK = GSTRUCK_{-1} + PGSTRUCK - PGSTRUCK_{-10}$$

(9) Demand for diesel oil by vehicles

$$DLVE = (-2739.10 + 43.4959 \cdot TRUCK + 15.1248$$
$$(-0.7) \qquad (6.0)$$
$$DSTRUCK)/(1 + 0.39492\ (\overline{RPDL}_{-1}/\overline{PGDP}_{-1} - 1))$$
$$(-1.5)$$

$$\overline{R}^2 = 0.833 \quad SD = 2072.4 \quad DW = 1.76$$

(10) Demand for gasoline and LPG by vehicles excluding motorcycles

$$GPPAS = (\underset{(-0.1)}{2868.72} + \underset{(5.9)}{12.6775} \cdot PASCAR + \underset{(3.2)}{15.1248}\, GSTRUCK)/(1 + \underset{(-7.9)}{0.67117}\,(\overline{RPGA}_{-1}/\overline{PGDP}_{-1} - 1))$$

$$\bar{R}^2 = 0.892 \quad SD = 350.0 \quad DW = 2.74$$

(11) Share of gasoline in total fuel consumption by vehicles excluding motocycles

$$\ln SGAPAS = 0.10945 - 0.05436 \cdot (\overline{RPGA} + \overline{RPGA}_{-1} + \overline{RPGA}_{-2} + \overline{RPGA}_{-3} - \overline{RPLP} - \overline{RPLP}_{-1} + \overline{RPLP}_{-2} + \overline{RPLP}_{-3})/(\overline{PGDP} + \overline{PGDP}_{-1} + \overline{PGDP}_{-2} + \overline{PGDP}_{-3})$$

$$\bar{R}^2 = 0.881 \quad SD = 0.03 \quad DW = 1.14$$

(12) Demand for gasoline by vehicles excluding motorcycles

$$GAPAS = SGAPAS \cdot GPPAS$$

(13) Demand for LPG by vehicles excluding motorcycles

$$LPPAS = GPPAS - GAPAS$$

(14) Demand for gasoline by motorcycles

$$GAMOTC = 2.956 \cdot MOTOCY$$

(15) Demand for gasoline by vehicles

$$GAVE = GAPAS + GAMOTC$$

Variables

Endogenous variables

TRUCK	: 10^3	: Number of trucks
PASCAR	: 10^3	: Number of passenger cars
DSTRCUK	: 10^3	: Number of diesel-fueled small trucks

GSTRUCK	: 10^3	: Number of gasoline-fueled small trucks
SPDSTRU	:	: Share of purchases of diesel-fueled small trucks
PDSTRUCK	: 10^3	: Purchases of diesel-fueled small trucks
PGSTRUCK	: 10^3	: Purchases of gasoline-fueled small trucks
MOTOCY	: 10^3	: Number of motorcycles
DLVE	: 10^{12} kcal	: Consumption of diesel oil by vehicles
GPPAS	: 10^{12} kcal	: Concumption of gasoline and LPG by vehicles excluding motorcycles
SGAPAS	:	: Share of consumption of gasoline by vehicles excluding motorcycles
GAPAS	: 10^{12} kcal	: Consumption of gasoline by vehicles excluding motorcycles
LPPAS	: 10^{12} kcal	: Consumption of LPG by vehicles excluding motorcycles
GAVE	: 10^{12} kcal	: Consumption of gasoline by vehicles
GAMOTC	: 10^{12} kcal	: Consumption of gasoline by motorcycles

Exogenous variables

$\overline{GDPR}$	:	10^6 ฿	:	Gross domestic product at constant 1982 prices
$\overline{PGDP}$	:	1980 = 1.0	:	GDP deflator
$\overline{PSTRU}$	:	10^3	:	Purchases of small trucks
$\overline{RPGA}$	:	฿/litre	:	Retail price of gasoline
$\overline{RPGAI}$	:	1980 = 1.0	:	Index of retail price of gasoline
$\overline{RPLP}$	:	฿/litre	:	Retail price of LPG
$\overline{RPLPI}$	:	1980 = 1.0	:	Index of retail price of LPG
$\overline{RPDL}$	:	฿/litre	:	Retail price of diesel oil
$\overline{RPDLI}$	:	1980 = 1.0	:	Index of retail price of diesel oil

Structure of the Model

The model consists of 15 equations, in which four are estimated above, three are from EMP model (equations for PASCAR, TRUCK, MOTOCY), one is the equation which converts the number of motorcycles to the fuel consumption by a fixed coefficient, and the others are identification equations. And in the equations which calculate the number of gasoline-fueled and diesel-fueled small trucks, the lifetime of the trucks is assumed to be 10 years.

In this model, prices of fuels, GDP and purchases of small trucks are given as exogenous variables. The numbers of vehicles and the fuel consumptions are determined by these exogenous variables. As shown by Figure II-5, at first numbers of passenger cars, trucks (total, gasoline-fueled and diesel-fueled small trucks) and motorcycles are determined by GDP and prices of fuels (for small trucks). And next, fuel consumptions are determined by the numbers of vehicles and prices of fuels.

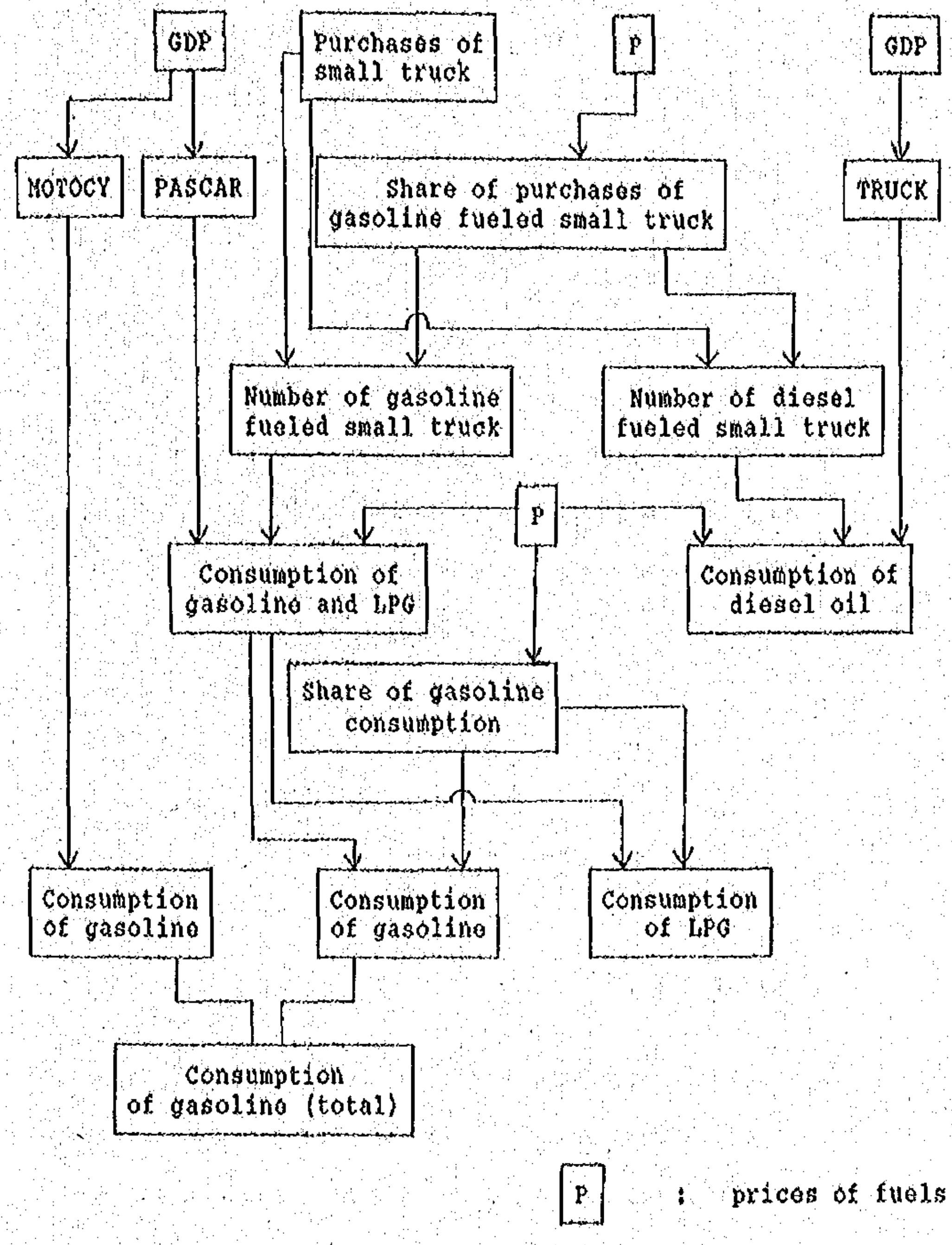

Fig. II-5 Flow Chart of the Model

2). Simulation

Simulations are conducted using the model for the period from 1985 to 2001.

Reference Case

This case if considered as the most probable scenario. Exogenous variables are set for the period as follows :

$\overline{GDPR}$: Annual growth rate

1984-1986 : 4.1% (average)

1986-1991 : 4.6% (average)

1991-1996 : 4.3% (average)

1996-2001 : 4.2%

$\overline{PGDP}$: Annual increase rate

1984-1986 : 2.5% (average)

1986-1991 : 1.9% (average)

1991-2001 : 2.0%

$\overline{PSTRU}$: Annual growth rate

1985-2001 : 2.0%

$\overline{RPGA}$, $\overline{RPLP}$, $\overline{RPDL}$

~1986 : Actual prices

1987-2001 : Annual growth rate 3% (Table 1)

Retail prices of fuels are assumed to increase at 3% per annum throughout the simulation period. Other exogenous variables are adopted from the input data to EMP model.

No Adjustment Case

This case is set to analyse the effects of price changes. In this case, for 1986 the relativities between fuel prices are assumed to be unchanged from those in 1985, and the average price of fuels decrease in the same rate as in Reference Case. And after 1986 the fuel prices increase at the same rate (3%) as in Reference Case (Table II-1).

By comparing these two cases, we can separate the effects on fuel consumption by the changes of relativities of prices from the total effects by the price changes.

Table II-1 Retail Prices of Petroleum Products Reference Case

(Baht/litre)

	1985	1986	1987	1988	1989
Gasoline	11.25	8.55	8.81	9.07	9.34
LPG	5.90	5.40	5.56	5.73	5.90
Diesel Oil	6.70	6.30	6.49	6.68	6.88

	1990	1991	1996	2001
Gasoline	9.62	9.91	11.49	13.32
LPG	6.08	6.26	7.26	8.41
Diesel Oil	7.09	7.30	8.47	9.82

Table II-2 Retail Prices of Petroleum Products

No Adjustment Case (Baht/litre)

	1985	1986	1987	1988	1989
Gasoline	11.25	10.08	10.38	10.69	11.02
LPG	5.90	5.29	5.44	5.61	5.78
Diesel Oil	6.70	6.00	6.18	6.37	6.56

	1990	1991	1996	2001
Gasoline	11.35	11.69	13.55	15.70
LPG	5.95	6.13	7.11	8.24
Diesel Oil	6.75	6.96	8.06	9.35

Table II-3 and Figure II-6 show the fuel consumption up to 2001 by the two cases. In Reference Case, diesel consumption increases at 5.2% per annum and gasoline consumption increases at 6.2% per annum on average in the period from 1986 to 2001. Especially from 1986 to 1991 gasoline consumption increases at a high growth rate (10.2% per annum) because of the decline of gasoline price. LPG consumption increases at a low growth rate (3.3% per annum) throughout the period (1986-2001), expecially from 1986 to 1991 it decreases slightly by the increase of relative price of LPG. And diesel oil consumption increases at 5.2% throughout the period, and at 7.0% from 1986 to 1991. Total consumption increases at 5.4% throughout the period, and at 7.7% from 1986 to 1991. The high growth rates of fuel consumptions excluding LPG are caused by the declines of fuel prices in 1986.

Table II-3 Fuel Consumptions, Reference Case and No Adjustment Case

10 kcal

	1986	1991	1996	2001	1986 -1991 %	1991 -1996 %	1996 -2001 %
Reference Case							
Gasoline	16,289	26,454	34,484	40,001	10.2	5.4	3.0
LPG	2,895	2,872	4,000	4,719	-0.1	6.9	3.4
Diesel Oil	31,892	44,777	53,981	68,035	7.0	3.8	4.7
Total	51,076	74,103	92,465	112,755	7.7	4.5	4.0
No Adjustment Case							
Gasoline	15,867	21,184	26,002	29,732	6.0	4.2	2.7
LPG	3,049	3,385	4,284	4,816	2.1	4.8	2.4
Diesel Oil	32,177	48,280	60,572	76,678	8.5	4.6	4.8
Total	51,073	72,849	90,858	111,226	7.4	4.5	4.1
Difference*)	%	%	%	%			
Gasoline	2.7	24.9	32.6	34.5	-	-	-
LPG	-5.0	-15.2	-6.6	-2.0	-	-	-
Diesel Oil	-0.9	-7.3	-10.9	-11.3	-	-	-
Total	-0.0	17.2	17.7	13.7	-	-	-

*) $\frac{\text{(Reference Case) - (No Adjustment Case)}}{\text{(No Adjustment Case)}} \times 100$

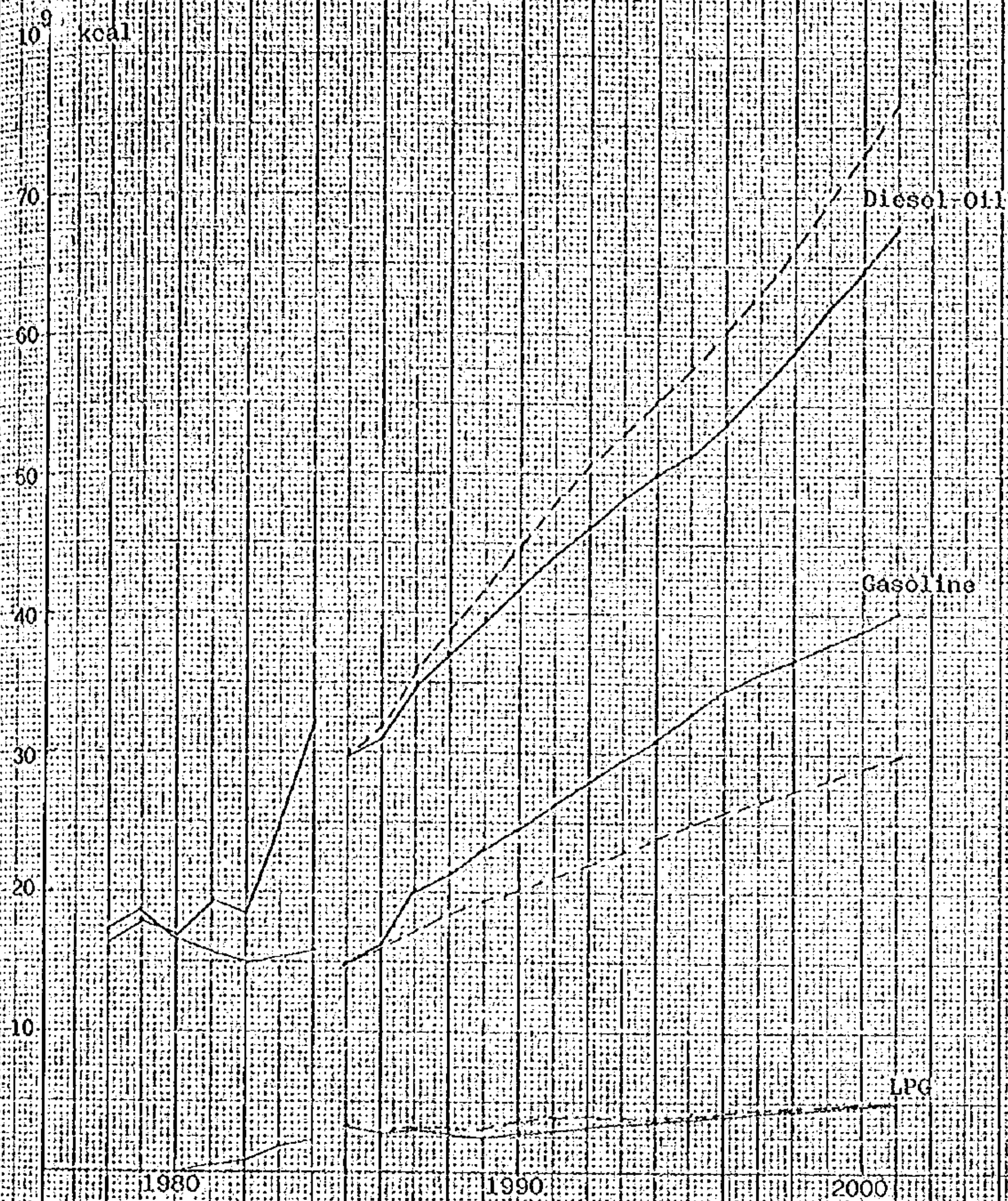

Figure II-6 : Fuel Consumption by Vehicles

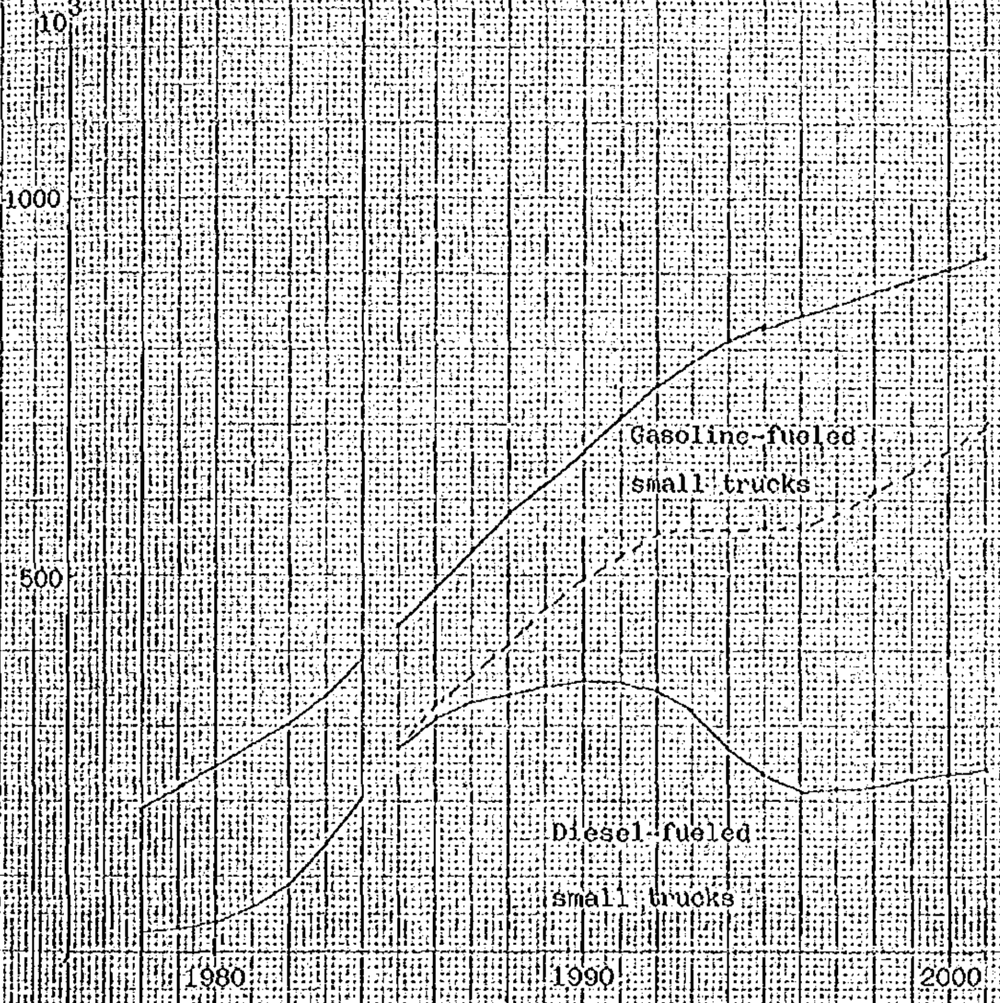

Figure II-7 : Number of Diesel-Fueled and Gasoline-Fueled Small Trucks

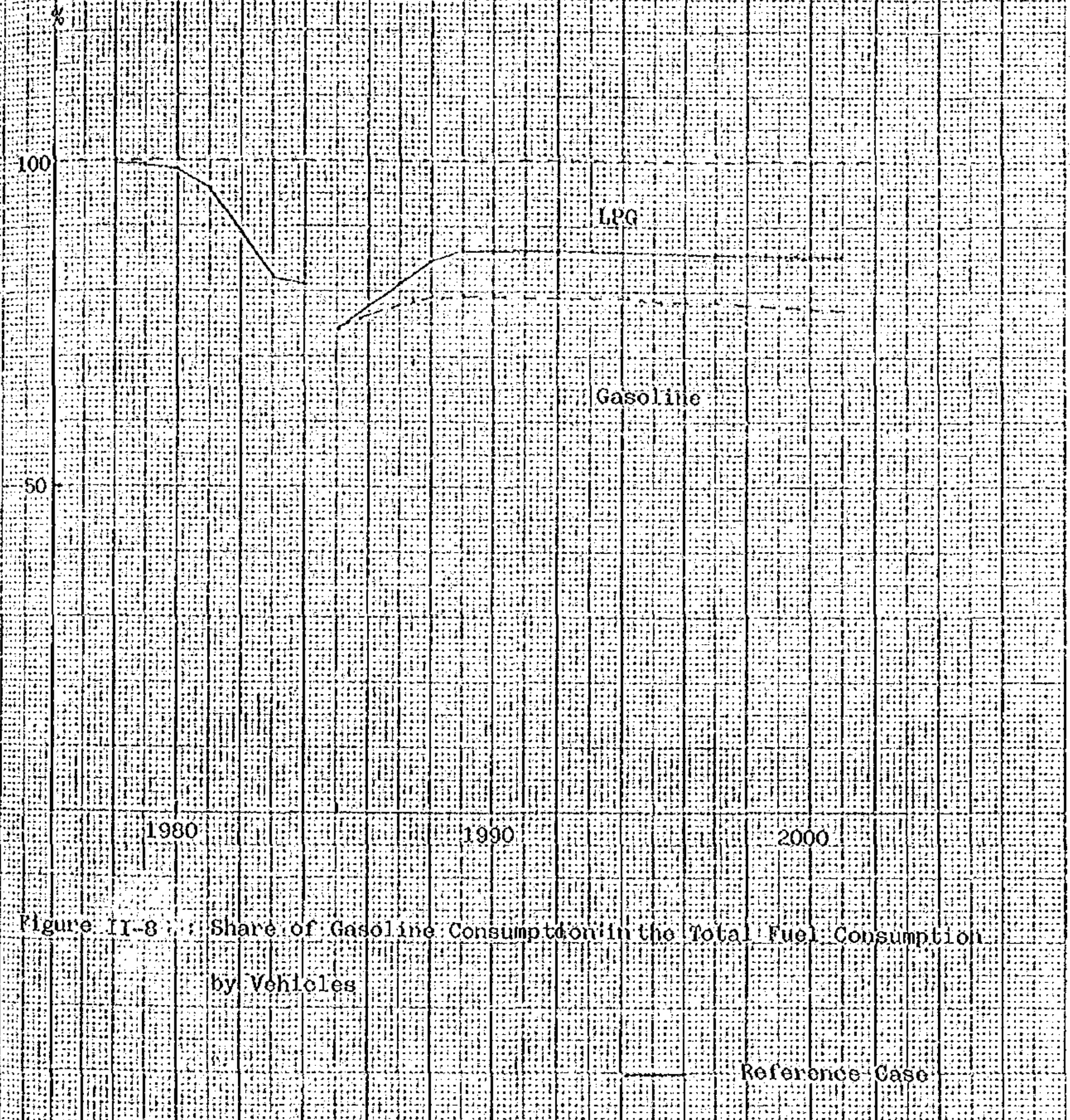

Figure II-8 : Share of Gasoline Consumption in the Total Fuel Consumption by Vehicles

The relatively high growth rate of gasoline consumption and the low growth rate of diesel oil can be explained by the changes of relativities between diesel oil price and gasoline price which took place in 1986. In No Adjustment Case, where the relative prices do not change in 1986, gasoline consumption increases at only 4.3% per annum and diesel oil consumption increases 6.0% per annum throughout the period. In 2001 gasoline consumption increases 34.5% and diesel oil consumption decreases 11.3% respectively of the consumptions in No Adjustment Case However, as for LPG the growth rate of consumption remain low in the two cases. This is because the decline of gasoline prices (even if the relative price to LPG price does not change) decrease the share of LPG in the sum of LPG and gasoline.

The effects by the changes of relativities of fuel prices can be seen in Figure II-7 and Figure II-8 Figure II-7 shows the number of diesel-fueled and gasoline-fueled small trucks. In this model, the substitution between gasoline and diesel oil is determined by the numbers of these two types of trucks. In Reference Case, the number of diesel-fueled small trucks increase at a low growth rate (3.2% per annum) from 1986 to 1991, and from 1991 it decrease up to 1996. The share of diesel-fueled small trucks in the total of small trucks will declined from 63% (1986) to 26% (2001). Comparing with No Adjustment Case, this declines of the share is explained predominantly by the changes of the relative prices.

Figure II-8 shows the share of gasoline consumption in the total fuel consumption by vehicles excluding motorcycles, which determines the substitution between gasoline and LPG. The share increases from 78% (1986) to 86% (1991), and after that stays in that level in Reference Case. Even in No Adjustment Case, the share increases slightly from 1986 to 1991 and after that stays at the level near 80%. The share of gasoline (LPG) in Reference Case becomes higher (lower) than No Adjustment Case throughout the period by the decline of the relative price of gasoline to LPG in 1986.

4. Conclusion

The purpose of this study is to attempt an econometric analysis on the mechanisms which determine fuel consumptions by vehicles. The results in this preliminary study show that this type of approach is useful in this field. And it was shown that fuel consumption by vehicles are predominantly determined by economic factors.

This study can be deepened more. The model presented above can be improved by the following ways, though most of them suffer from the lack of data.

1). Improving the estimated behavioural equations by, for example, introducing fuel prices to the equations which determine the numbers of passenger cars, trucks and motorcycles.

2). Making some of the exogenous variables (PSTRUCK --) endogenous by introducing equations which determine them.

3). Modifying the model by introducing new equations or variables to explain functional relations such as the substitution between gasoline and diesel oil by modifying vehicles, the consumption of LPG by small trucks, etc.

4). Modifying the structure of the model fundamentally, introducing new variables such as numbers of buses and large trucks, and fuel consumptions by them, or moreover passenger-kilometres and freight-kilometres by type of transport, and fuel consumptions by type of fuel and by type of transport etc.

III. On the Prices of Crude Oil and Petroleum Products *

The purpose of this study is to analyse the relations between crude oil prices and petroleum products prices (in their movements and relativities) in the recent years, and to give some conception for the future.

Analyses are performed by time-series regression analysis using monthly data from January 1982 to July 1986. Only a small number of variables on prices and some others which reflect the condition in the world market of crude oil and petroleum products are used, and the observation period is only four and a half years. So, what we can examine is limited in a very narrow field.

1. Price Decline in This Year

Crude oil price declined drastically by the change of the OPEC's supply policy in this year. In this section, the nature of the price changes is examined.

Figure III-1 and 2 show the movements of spot prices and posted prices of crude oil and petroleum products. Prices for Arabian light is used for crude oil, and average price of petroleum products weighted by the yield structure in 1984 of Singapore refineries is used for petroleum products.

Figure III-1 shows the relation between spot price posted

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* I owe Miss Prapapan Compiling data and estimating equations.

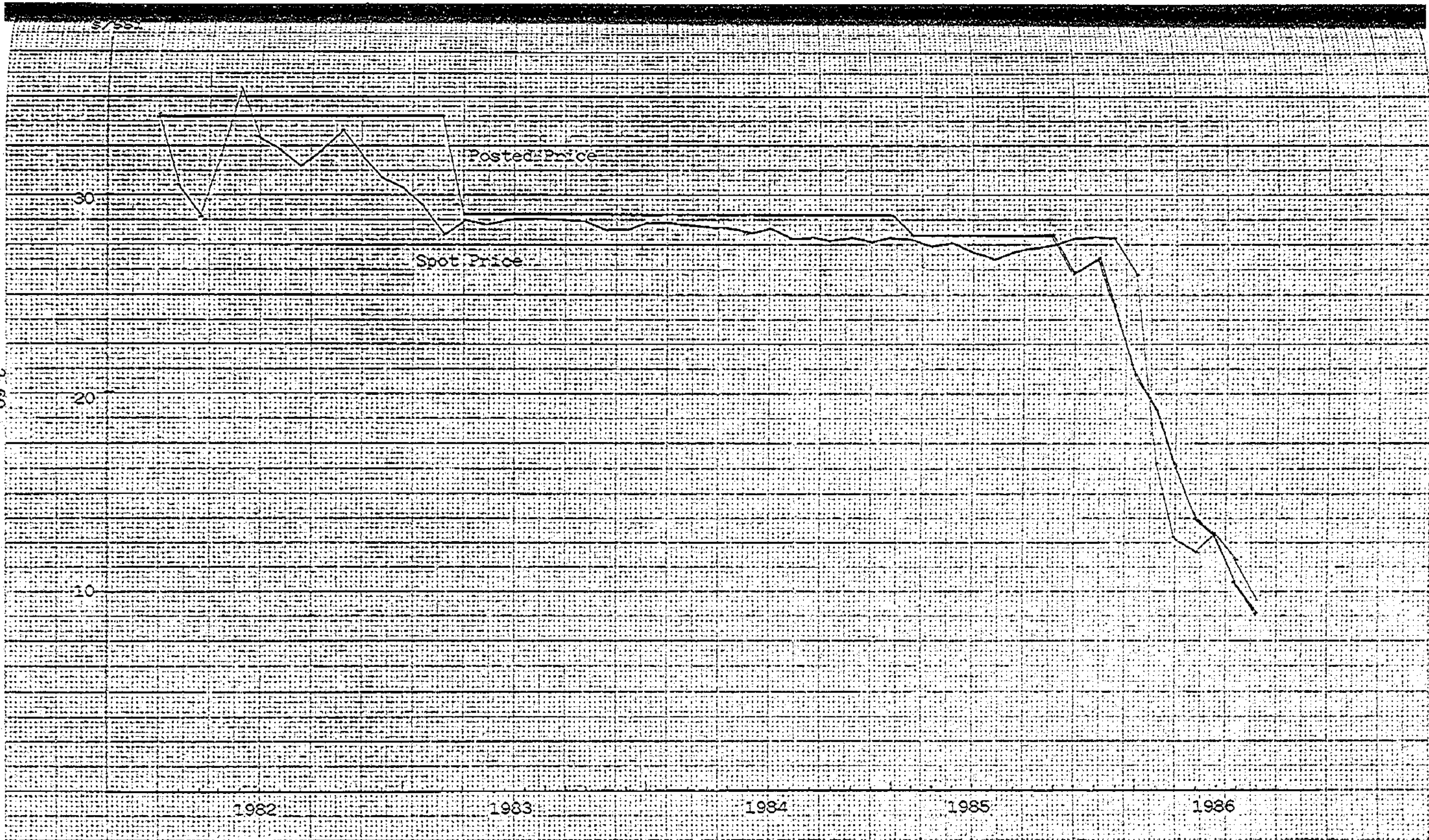

Figure III-1 : Comparison of Posted Price and Spot Price of Crude Oil

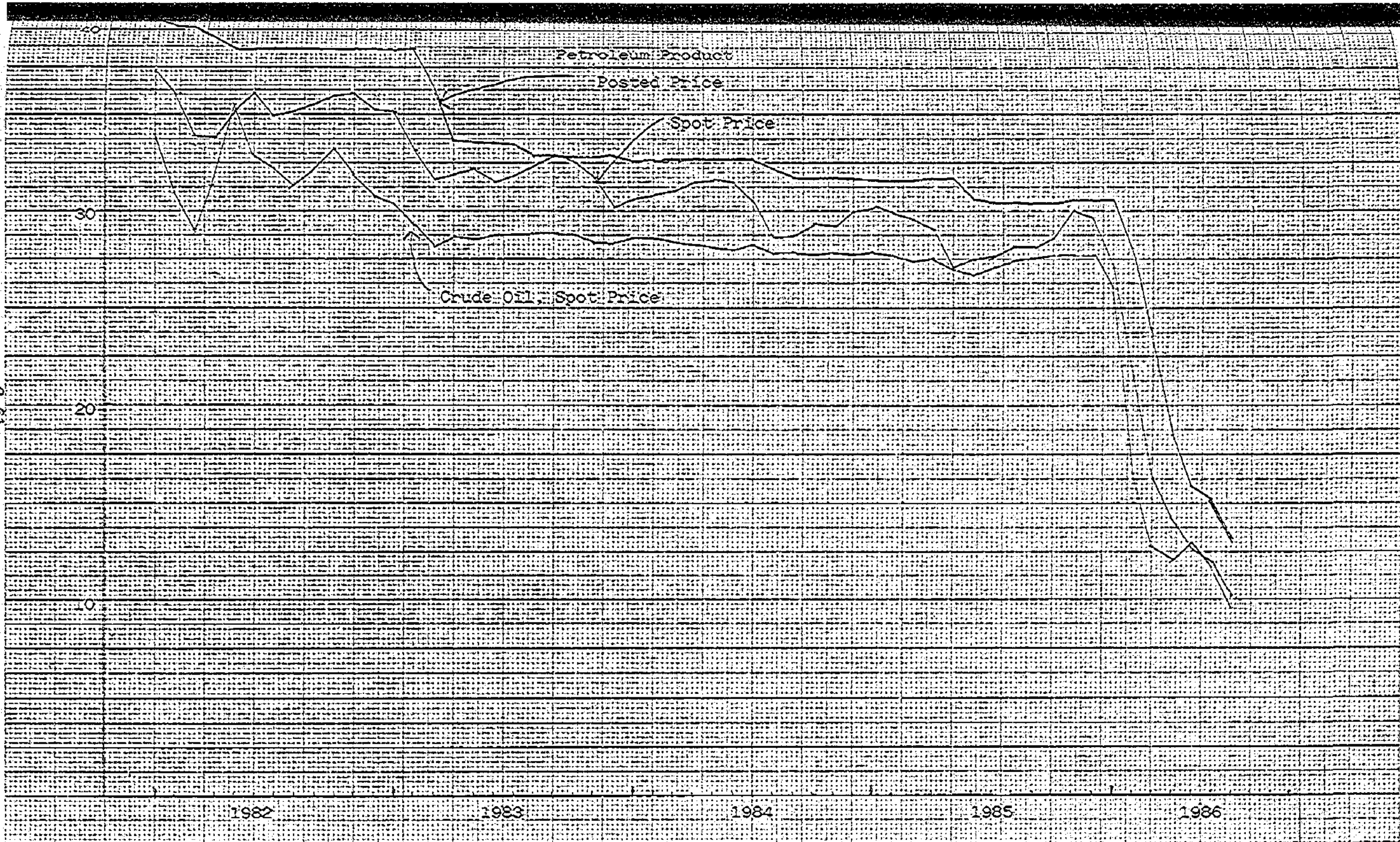

Figure III-2 : Comparison of Posted Price and Spot Price of Petroleum Products, and Spot Price of Crude Oil price of crude oil. It should be noted that for this time (not as in the case of 1982-3) the spot price started to decline after the posted price.

As shown in Figure III-2 the average price of products moves following both the spot prices of crude oil and products with a few months' lag.

Taking the spot price of crude oil, some interpletation on the recent decline is attempted.

It may be accepted that world price of crude oil is determined mainly by it's supply and demand in the world market. At least in the long-run, crude-oil price is determined as a equiliblium price for supply and demand.

Demand function for crude oil is specified economically with the explanatary variables such as the world total GNP and price of crude oil. On the other hand, the supply function, if specified economically (as for demand function) is not stable and shifts sometimes drastically (as supply decreases in the oil crisis and supply increase in this year).

By this fact, we may be able to identify the demand function using the actual price and supply (demand) data.

$$Q = f(P, Y)$$

where, Q : supply (demand) of crude oil

P : price of crude oil

Y : world total GNP

$$\text{or,} \quad \ln P = a + b \ln Q + c \ln Y$$

Crude oil price is determined by this equation. For estimation, we assume, growth rate of the world GNP, 4% per annum, and the elasticity of demand to GNP, 0.8. Replace these values in the equation above, we get.

$$\ln P - 0.8 \cdot 0.00327 \cdot TIME = a + b \ln Q$$

The estimated result for this equation is

$$\ln ALSPOT - 0.00262 \cdot TIME = \underset{(111.4)}{3.25102} - \underset{(-8.0)}{3.50011} \ln QWO/QWOAVL$$

$$\bar{R}^2 = 0.539 \quad SD = 0.21 \quad DW = 0.353$$

where, ALSPOT : Spot price of Arabian light crude oil

QWO : world supply of crude oil

QWOAV : average monthly supply of crude oil for the estimation period

Here, world supply of crude oil is devided by average monthly supply of crude oil for the estimation period to exclude the effect by the seasonal changes of supply. By the low values of R^2 and DW, this equation explains only long-run trend of the price. So, the price determined by this equation should be understood as a long-run equiliblium price. And the actual spot price fluctuates around the long-run equiliblium price, because of time lag and expectation.

The values of estimated parameters depend on the assumptions on GNP growth rate and elasticity of demand, and the estimation period. So, the estimated result should be understood as an example of probable ones. According to this, the equiliblium price of crude oil is 15.5 $/bbl at the trough in 1986 and 16.5 $/bbl in 1987 (if world supply does not change from the level at July in 1986). And, decrease of 10% of world supply of crude oil will induce increase of 35% of crude oil price.

2. Crude Oil Price and Petroleum Products Prices

In this section, the relations between posted prices of crude oil and petroleum products are analysed.

For estimation, posted price of Arabian Light, and posted prices of petroleum products at Singapore are used.

As posted price of crude oil affects on posted prices of petroleum products with time lag, the following function is used for estimation.

$$\ln PPi = a + b \cdot \ln PC + C \cdot \ln PPi_{-1}$$

where PPi : posted prices of petroleum products

PC : posted price of crude oil

i : types of petroleum products

In the equation, b is the short-run elasticity of PPi to the change of PC. And, the long-run elasticities can be calculated by b/(1-c). The equations are estimated as follows.

$$\ln PGPOST = \underset{(3.1)}{0.45400} + \underset{(6.2)}{0.26543} \cdot \ln ALPOST + \underset{(8.3)}{0.62752} \cdot \ln PGPOST(-1)$$

$\bar{R}^2 = 0.973$ SD = 0.03 DW = 0.934

$$\ln RGPOST = \underset{(2.6)}{0.39701} + \underset{(5.7)}{0.32854} \cdot \ln ALPOST + \underset{(6.3)}{0.57392} \cdot \ln RGPOST(-1)$$

$\bar{R}^2 = 0.965$ SD = 0.04 DW = 1.119

$$\ln HDPOST = \underset{(-1.2)}{-0.10341} + \underset{(7.5)}{0.34140} \cdot \ln ALPOST + \underset{(11.9)}{0.70404} \cdot \ln HDPOST(-1)$$

$\bar{R}^2 = 0.981$ SD = 0.03 DW = 1.79

$$\ln LDPOST = \underset{(-7.8)}{-0.42655} + \underset{(7.8)}{0.33437} \cdot \ln ALPOST + \underset{(13.7)}{0.73462} \cdot \ln LDPOST(-1)$$

$\bar{R}^2 = 0.983$ SD = 0.03 DW = 1.653

$$\ln KEPOST = \underset{(-2.5)}{-0.20794} + \underset{(8.8)}{0.27533} \cdot \ln ALPOST + \underset{(18.0)}{0.79913} \cdot \ln KEPOST(-1)$$

$\bar{R}^2 = 0.984$ SD = 0.03 DW = 1.598

$$\ln FOPOST = \underset{(-3.2)}{-0.29318} + \underset{(5.6)}{0.42057} \cdot \ln ALPOST + \underset{(7.0)}{0.65589} \cdot \ln FOPOST(-1)$$

$\bar{R}^2 = 0.978$ SD = 0.04 DW = 1.627

$$\ln LPGPOST = \underset{(-0.9)}{-0.08804} + \underset{(5.7)}{0.15417} \cdot \ln ALPOST + \underset{(17.2)}{0.87016} \cdot \ln LPGPOST(-1)$$

$\bar{R}^2 = 0.986$ SD = 0.02 DW = 1.108

Where

ALPOST : \$/bbl : Arabian light posted price

PGPOST : \$/bbl : Premium gasoline posted price at Singapore

RGPOST : \$/bbl : Regular gasoline posted price at Singapore

HDPOST : \$/bbl : High speed diesel posted price at Singapore

LDPOST : $/bbl : Low speed diesel posted price at Singapore

KEPOST : $/bbl : Kerosene posted price at Singapore

FOPOST : $/bbl : Fuel oil posted price at Singapore

LPGPOST : $/bbl : LPG posted price at Singapore

Short-run and long-run elasticities for each product are presented in the Table.

Table III-1 : Elasticity to Crude Price Changes

	Short-Run	Long-run
Premium Gasoline	0.27	0.71
Regular Gasoline	0.33	0.77
High Speed Diesel	0.34	1.15
Low Speed Diesel	0.33	1.26
Kerosene	0.28	1.37
Fuel Oil	0.42	1.22
LPG	0.15	1.19

As for the short-run elasticities, except fuel oil and LPG, the elasticities are estimated around 0.3. The elasticity of fuel oil is higher, and that of LPG is lower than the others. The values of long-run elasticities are devided into two groups, gasolines and the other products. The elasticities for gasolines are lower than 1.0, and this means that the prices of gasolines are more stable than that of crude oil. And for the other products, the elasticities are more than 1.0, and the prices are less stable than that of crude oil. Looking on both long-run and short-run elasticities (for example calculate (long-run elasticity)/(short-run elasticity), the speed of adjustment of gasoline prices to the changes of crude oil price is higher than the other products (more than one third of the total effect by the crude price change takes place in the first year). And that of LPG is the lowest (a little more than 10% of the total effect takes place in the first year).

Using the equations, prices of petroleum products up to 1990 are estimated. For the crude oil price, the forecast by EMP project (Base Case) is used. Calculation is started at February 1986.

Table III-2 : Assumption on the Crude Oil Prices

US$/bbl

1986	1987	1988	1989	1990
14.44	17.00	19.50	21.00	22.00

Table III-3 : Results

	June 1986	June 1987	June 1988	June 1989	June 1990
Premium Gasoline	21.7	23.8	27.7	29.4	30.5
Regular Gasoline	18.3	21.3	24.8	26.4	27.5
High Speed Diesel	15.6	16.0	21.0	23.3	24.7
Low Speed Diesel	12.3	14.1	19.3	21.7	23.2
Kerosene	17.4	13.7	19.3	22.3	24.1
Fuel Oil	10.6	12.0	15.7	17.4	18.5
LPG	17.2	12.2	15.5	17.8	19.3
Average*	15.3	15.3	19.8	21.9	23.3

* Weighted average by the yield structure of Singapore refineries in 1984

With the different time lags, prices of kerosene and LPG will decline until 1987, but prices of the other producs will increase from this year. According to the results, the prices of diesel oil and kerosene are relatively low relatively to the prices of gasoline, compared with those before the price decline which started at the end of 1986. These estimated prices are affected by the changes of relative prices (decline of relative prices of diesel oil and kerosene to gasoline) accompanied with the price decline in this year.

Figure III-3 show the movements of prices of selected products until the end of 1987. The estimates up to July 1986 are very close to their actual values.

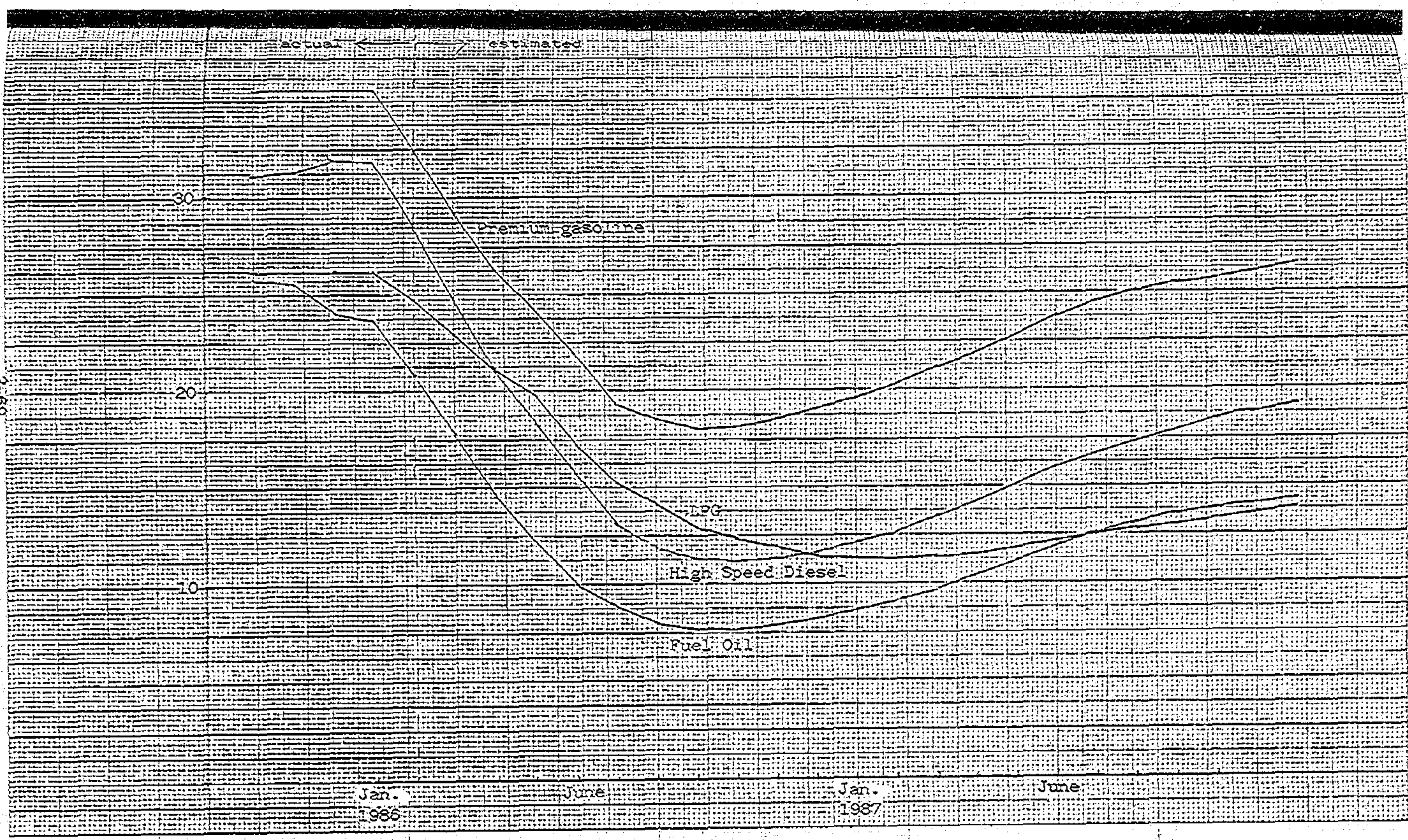

Figure III-3 : Prices of Selected Product Prices