4-2 Energy in Thailand by Type and Source

4-2-1 Commercial Energy

(1) Coal and Lignite

There is almost no high-grade coal in Thailand; however, a large amount of lignite, or low-grade coal, exists especially in the northern area. Though there has been no detailed survey conducted on the coal reserves, the proven, probable and original reserves are estimated at 900, 1,700 and 2,400 million tons, respectively.

At present, there are 12 coal mines reportedly in operation in Mae Moh, Krabi, Ban Pa Kha in Li District and others. Mae Moh is the largest among them with reserves estimated at 800 million tons. Table 4-7 gives an outline of the operating coal mines.

Table 4-7 Outline of Coal Mines

Name	Province	Reserve (MM tons)	Production (MM tons)	Proprietors
Mae Chaem	Chiang Mai	1.20	0.138	Private
Mae Teep	Lampang	11.00	0.519	Private
Mae Moh	Lampang	820.90	36.398	EGAT
Mae Than	Lampang	1.20	0.097	Private
Li	Lamphun	28.00	6.289	NEA/Private
Mae Tuen	Tak	1.23	0.323	Private
Mae Lamao	Tak	1.63	0.137	Private
Nong Ya Plong	Phetchaburi	1.40	0.465	Private
Krabi	Krabi	83.60	6.631	EGAT
Kan Tang	Trang	n.a.	400 tons	Private
Na Duang	Loei	n.a.	61,740 tons	Private
Na Klang	Udon Thani	n.a.	6,475 tons	Private

Note: 1) Reserve: Mineable Reserve
2) Production: As of end of May 1990
Source: DMR

Lignite production increased from 1.36 million tons in 1979 to 8.90 million tons in 1989 at an average rate of 20 percent per year, concerning which reference should be made to Chapter 3, Table 3-12. This increase is due mainly to the rapid increase in production at the Mae Moh Mine.

The coal from the Mae Moh and Krabi Mines, both belonging to EGAT, is mostly low-grade lignite and is burned exclusively by the power stations located at these mines. The important properties of Mae Moh lignite are a heating value of 2,700kcal/kg, an ash content of 25 percent, and a moisture content of 30 percent. The mines operated by private companies produce lignites of better quality compared with those produced by EGAT. Incidentally, NEA has leased two mines in Li District to private companies. High-quality coal such as anthracite or bituminous coal and coke are all imported. Imports in 1989 totaled about 480 thousand tons, as shown in Table 4-8. The imported coal and coke are consumed by industries like cement plants and metallurgical industries.

Table 4-8 Coal and Coke Import

(Unit: Thousand Tons)

	Steam Coal	Anthracite	Coke	Others	Total
1979	n.a.	n.a.	n.a.	n.a.	66
1980	n.a.	n.a.	n.a.	n.a.	90
1981	n.a.	n.a.	n.a.	n.a.	66
1982	94	4	62	0	160
1983	96	3	71	0	170
1984	141	4	81	0	226
1985	242	8	86	0	336
1986	179	4	40	0	223
1987	250	4	58	0	312
1988	297	7	76	0	380
1989	380	6	85	6	477

Source: Thailand Energy Situation, NEA

Except for these imports, almost all the coal consumed in Thailand is lignite. The consumption of lignite has been increasing rapidly, especially for power generation. In 1989, Thailand consumed 8.6 million tons of lignite, 6.8 million tons or an overwhelming 79 percent for power generation, 1.27 million tons or 15 percent by the cement industry, and 0.11 million tons or less than 1 percent for tobacco curing. Concerning the uses of lignite, reference should be made to Table 3-13.

Coal is consumed mainly by the power stations located at mines; only about 20 percent of the total production is transported over long distances by truck.

(2) Natural Gas and Crude Oil

1) Natural Gas

Full-scale exploration for natural gas in Thailand began in 1971. The commercial production of natural gas started in 1981 in Concession Nos. 12 and 13 in the Gulf of Thailand leased jointly to Union Oil Co. and South East Asia Exploration Co. The proven reserves of natural gas in 1989 were 6,910 billion cubic feet; the probable reserves were 8,645 billion cubic feet. The total reserves were 15,555 billion cubic feet.

Currently, natural gas is produced in Erawan, Baanpot, Satun, Platong and in other gas fields in the Gulf of Thailand. As can be seen from Table 4-9, production in 1989 reached 211 billion cubic feet. Onshore, a gas field has been discovered by a group led by Esso at Nam Phong on the Korat Plateau in Northeast Region. However, a long period of preparation will be required before production can actually start, because the development of the field needs the construction of a pipeline to Bangkok, the only conceivable center of consumption, over a distance of about 400 kilometers.

Table 4-9 Historical Production of Natural Gas

(Unit: Billion Cubic Feet)

	1981	1982	1983	1984	1985	1986	1987	1988	1989
Offshore									
Erawan	10.8	47.1	53.8	68.2	67.4	59.0	76.3	79.1	80.8
Baanpot	--	--	1.0	11.1	8.1	--	3.8	21.5	22.6
Plathong	--	--	--	--	21.8	25.5	25.3	27.6	23.7
Sutun	--	--	--	--	24.9	32.6	62.0	72.3	67.7
Nang Nuan	--	--	--	--	--	--	--	0.0	--
Kaphong	--	--	--	--	--	--	--	--	4.7
Offshore Total	10.8	47.1	54.8	79.3	122.3	117.1	167.4	200.5	199.5
Onshore Total	--	--	1.9	6.2	10.0	10.6	11.3	11.1	11.9
Total	10.8	47.1	56.7	85.5	132.3	127.8	178.7	211.6	211.4

Source: Oil and Thailand, NEA

Production is targeted to reach between 328 and 365 billion cubic feet per year in 1996. However, the producing fields have only about ten times the current annual demand; new gas fields have to be developed to achieve this goal.

The natural gas produced in the Gulf of Thailand is transported to the gas separation plant at Rayong in the East Coast Industrial Zone located 140 kilometers to the southeast of Bangkok, through the longest submarine pipeline in the world, 435 kilometers long and 34 inches in diameter, constructed by Petroleum Authority of Thailand, PTT. The gas is further transported from Rayong to the South Bangkok Power Station through a 169-kilometer onshore pipeline. Gas is also supplied to the Bang Pakong Power Plant on the way.

The Bang Pakong Power Station had a capacity of 1,870MW as of the end of 1989, of which 1,580MW can be generated by burning natural gas. The South Bangkok Power Station is rated at 1,300MW and can be generated solely by natural gas. In addition, the North Bangkok Power Station has a plan for fuel conversion to natural gas, and the construction of a pipeline to the power station is now under study. Besides power generation, the two cement plants of Siam Cement have used natural gas. The number of industrial consumers of natural gas is increasing as PTT promotes sales to industrial facilities. About 3,000 cubic feet per day of the natural gas produced in association with the Phet crude oil from the Sirikit oil field to the northeast of Bangkok is supplied to EGAT's 5.5MW gas-turbine power station there.

The gas separation plant in Rayong has been in operation at capacity since April 1985. This plant has a capacity to process 350 million cubic feet per day of natural gas to produce 230 million cubic feet a day of methane, 320 thousand tons per year of ethane, 450 thousand tons per year of propane and butane, and 66 thousand tons per year of NGL. Butane and propane are sold as LPG for motor fuel and household uses in various parts of the country. LPG is transported from the gas separation plant in Rayong to a terminal in Chonburi through a pipeline, from there to depots in Nakhon Swan, Lampang and Khon Kaen by rail, and to coastal depots in Bangchak, Surat Thani and Songkula, the latter being under construction, by sea. LPG is delivered to consumers by truck from depots located in various parts of the country. Some ethane and propane are planned to be used as petrochemical feedstocks in the future; they are now mixed again into the processed natural gas. NGL is used by domestic refineries as a feedstock for

gasoline production. Methane is used as a fuel for power generation, cement production and others.

2) Petroleum

Until 1980, oil production in Thailand had been in the range of only several hundreds of barrels per day from a small field in Fang in Chiang Mai Province, and the demand had been met almost exclusively by imports. No intensive exploration for oil resources had been carried out. However, the discovery of natural gas and condensate in the Gulf of Thailand and the energy crisis in 1973 prompted exploration and development of oil resources. In addition to the natural gas and condensate which Thailand already had, the Sirikit oil field, the first commercial-scale oil field, was discovered in 1981 in Lan Krabue in the northern part. The Erawan gas field in the Gulf of Thailand started production in August 1981, the Sirikit oil field in April 1983, and the Baanpot gas field in the Gulf of Thailand in October 1983, in rapid succession. The production of condensate has been increasing as the production of natural gas increases. The production of crude oil has also been steadily increasing since 1983, as shown in Table 4-10.

Table 4-10 Historical Production of Crude Oil & Condensate

(Unit: Million Barrels)

	1981	1982	1983	1984	1985	1986	1987	1988	1989
Crude Oil									
Fang	0.1	0.1	0.2	0.3	0.3	0.4	0.4	0.4	0.4
Sirikit	--	--	2.2	5.1	7.6	7.3	6.1	6.5	7.3
Nang Nuan	--	--	--	--	--	--	--	0.5	--
Total	0.1	0.1	2.4	5.4	7.9	7.7	6.5	7.4	7.8
Condensate									
Erawan	0.5	2.0	2.4	2.4	2.6	2.4	2.3	2.3	2.7
Baanpot	--	--	0.0	0.6	0.3	--	0.2	0.8	0.7
Plathong	--	--	--	--	1.2	1.5	1.3	1.4	1.2
Sutun	--	--	--	--	1.0	1.2	1.7	2.0	2.0
Kaphong	--	--	--	--	--	--	--	--	0.2
Total	0.5	2.0	2.4	3.0	5.2	5.2	5.5	6.6	6.7

Source: Oil and Thailand, NEA

The degree of crude oil self-sufficiency increased with the increase in the production of domestic crude oil and condensate. About 14 percent

of the total supply of crude oil and condensate was provided by the domestic sources in 1984. Thailand began exporting condensate in 1983 as production increased. In 1989, 5.65 million barrels, or 84 percent of the total production of condensate, were exported.

(3) Crude Oil Imports

Although the production of domestic crude oil has been increasing, as stated previously, Thailand still depends heavily on imports for its crude oil supply. In 1988, 7,509 KTOE of crude oil was imported, accounting for 84 percent of the total supply. Crude oil imports had leveled off from 7,247 KTOE in 1982 to 7,509 KTOE in 1988. However, crude oil imports increased sharply in 1989 to 10,143 KTOE, or 91 percent of the total supply, reflecting the country's rapidly expanding economy.

There has been a shift in the country of source, as shown in Table 4-11. Thailand has been importing more from Asian countries such as Malaysia and Brunei, and less from OPEC countries since the second energy crisis. This is a result of an endeavor Thailand has been making to diversify its sources of supply by increasing imports on a G-G basis in order to secure a stable supply of crude oil since Thailand had bitter experiences in the two energy crises. Imports of crude oil and petroleum products on a G-G basis are undertaken by PTT.

Table 4-11 Crude Oil Import by Country

(Unit: %)

	1975	1978	1983	1988	1989
Saudi Arabia	50.2	37.2	57.4	11.2	15.7
Kuwait	13.5	9.0	0.9	9.6	9.1
Qatar	20.4	27.4	7.2	6.5	7.5
UAE	--	--	2.4	26.7	21.9
Oman	--	--	--	7.4	4.6
Other OPEC	4.5	11.0	1.0	--	12.9
OPEC Total	88.7	84.6	68.9	61.4	71.6
Brunei	7.0	9.2	7.5	18.0	13.2
Malaysia	--	--	23.6	17.1	13.2
Other Countries	4.3	6.2	0.0	3.5	2.0
Non-OPEC Total	11.6	15.4	31.1	38.6	28.4

Source: Oil and Thailand, NEA

(4) Petroleum Products

1) Consumption

Table 4-12 illustrates the consumption of petroleum products. Total consumption peaked at 12.67 million kiloliters or 218 thousand barrels per day (b/d) in 1980, increasing from 1973 at an average rate of 6.9 percent. Consumption showed a temporary decline in 1981 and 1982. Since then, consumption has been increasing. In 1989, 19.42 million kiloliters, or 335 thousand b/d, were consumed.

The decline in consumption in 1981 was brought about not only by increased product prices and the economic recession after the second oil crisis, but also by the shift in fuel from fuel oil to domestic natural gas for power generation, as is obvious from Table 4-12.

Table 4-12 Consumption of Petroleum Products

(Unit: Million Liters)

	LPG	Gasoline	Aviation Fuel	Kerosene	Diesel	Fuel Oil	Total
1973	144	1,480	883	198	2,836	2,392	7,933
1974	161	1,496	714	187	2,664	2,724	7,946
1975	195	1,977	835	212	3,221	2,622	9,061
1976	208	1,972	855	238	3,318	2,884	9,475
1977	251	2,180	763	258	3,780	3,425	10,657
1978	284	2,301	786	275	4,119	4,095	11,859
1979	369	2,361	869	312	4,298	3,994	12,204
1980	354	2,249	944	290	4,110	4,721	12,669
1981	450	2,091	927	389	4,030	4,143	12,029
1982	601	2,015	1,081	388	3,931	2,997	11,013
1983	831	2,067	1,142	538	4,402	3,364	12,345
1984	962	2,118	1,206	290	5,259	3,125	12,960
1985	1,140	2,090	1,238	154	5,522	2,281	12,424
1986	1,201	2,269	1,370	143	5,739	2,410	13,132
1987	1,282	2,597	1,490	129	6,428	2,346	14,271
1988	1,427	2,923	1,835	126	7,215	2,800	16,326
1989	1,601	3,328	2,170	120	8,524	3,682	19,424

Source: Oil and Thailand, NEA

Until 1980, the patterns of demand for petroleum products had remained about the same: fuel oil and diesel oil each had accounted for 30 percent of the total demand, gasoline 20 percent, and jet fuel, kerosene and LPG the remaining a little over 10 percent. From 1980 onwards,

there have been noticeable changes occurring in the demands for various products other than the decline in the demand for fuel oil. First, the share of gasoline decreased. Second, the demand for LPG has been increasing rapidly. The growth of LPG consumption was 17 percent per year for the period from 1973 to 1979, and 19 percent for the period from 1980 to 1988; in other words, the growth rate after the second energy crisis was higher than that before the crisis. Third, the demand for diesel oil has shown a steady growth. The primary factor causing these changes is the structure of the prices of petroleum products, namely, a heavy tax on gasoline. In Thailand, the prices of petroleum products are controlled by the government.

2) Capacities of the Refineries

Tables 4-13 and 4-14 show the capacities of the refineries, and the throughputs and outputs, respectively. As may be seen from these tables, the nation's refineries have not coped well with the changing patterns of demand for individual products. Esso's refinery was expanded from 45,000b/d in 1980 to 63,000 b/d in 1985, and the TORC Refinery was expanded from 65,000 b/d in 1980 to 83,500 b/d in 1989. Obviously, the refining capacity does not meet the demand.

Table 4-13 Official and Utilized Refinery Capacity

(Unit: Barrels per Day)

	1980	1985	1987	1988	1989
Official Capacity					
TORC	65,000	65,000	65,000	65,000	83,500
BANGCHAK	65,000	65,000	65,000	65,000	68,000
ESSO	45,000	63,000	63,000	63,000	63,000
FANG	1,000	1,000	1,000	1,000	1,100
Total	176,000	194,000	194,000	194,000	215,600
Total Utilized Capacity	171,459	181,135	196,650	203,264	248,108

Source: Oil and Thailand, NEA

Table 4-14 Refinery Throughput and Output of Petroleum Products

(Unit: Million Liters)

	1982	1983	1984	1985	1986	1987	1988	1989
Throughput								
Crude Oil	9,002	9,094	8,881	9,098	9,811	9,998	10,351	12,821
Condensate	224	426	441	406	260	320	314	196
Total	9,226	9,520	9,322	9,504	10,071	10,318	10,665	13,017
Output								
LPG	194	228	245	247	249	273	307	348
Gasoline	1,982	2,063	2,007	2,041	2,200	2,407	2,510	2,700
Aviat'n Fuel	949	1,060	1,023	1,029	1,149	1,126	1,301	1,650
Kerosene	361	433	245	165	148	141	129	129
Diesel Oil	2,845	3,052	2,768	3,359	3,675	3,666	3,501	4,212
Fuel Oil	2,369	2,161	2,463	2,123	2,189	2,135	2,529	3,487
Bitumen	124	128	147	147	170	158	160	174
Total	8,822	9,125	8,897	9,111	9,779	9,905	10,438	12,698

Source: Oil and Thailand, NEA

3) Imports of Petroleum Products

The changes that have occurred in the patterns of demand for petroleum products and the insufficient refining capacity have created a gap between the supply and demand of petroleum products. The products that are not domestically supplied in sufficient quantities are supplemented by imports. The changes in the degree of self-sufficiency of major petroleum products are shown in Figure 4-2, and the volumes of imported petroleum products in Table 4-15.

Table 4-15 Volume of Petroleum Products Imported

(Unit: Million Liters)

	1982	1983	1984	1985	1986	1987	1988	1989
LPG	426	603	721	237	107	233	276	709
Gasoline	5	--	66	39	8	223	351	621
Aviation Fuel	120	89	199	160	214	393	555	487
Kerosene	67	117	52	10	--	--	--	--
Diesel Oil	1,165	1,251	2,550	2,148	2,107	2,666	3,669	4,316
Fuel Oil	632	1,240	705	208	82	336	286	247
Total	2,415	3,300	4,294	2,802	2,518	3,850	5,137	6,380

Source: Oil and Thailand, NEA

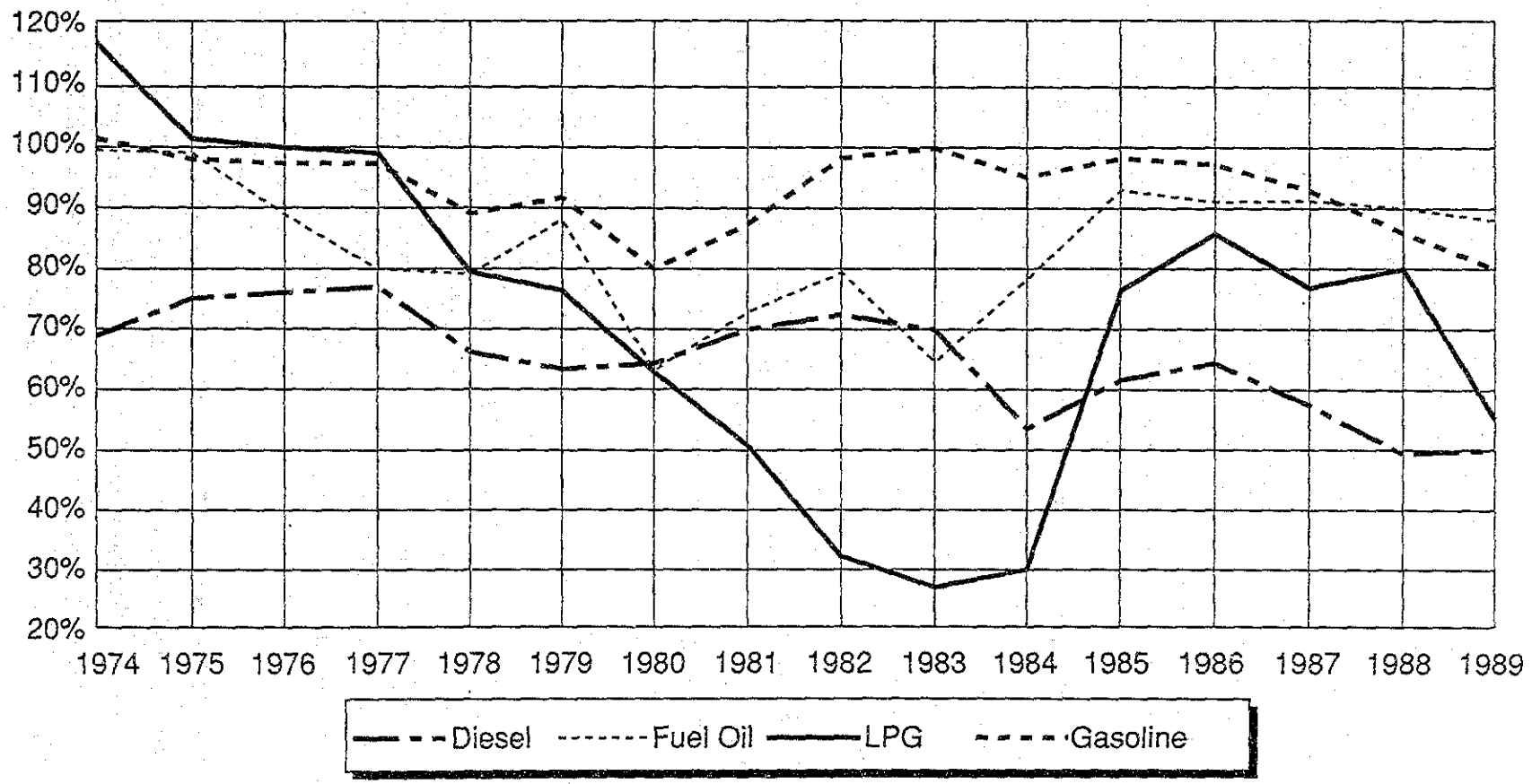

Figure 4–2 Self Sufficiency Rate of Major Petroleum Products

The importation of petroleum products had been increasing until 1984 when it peaked at 4.3 million kiloliters. After 1984, the importation suddenly dropped, but it has been steadily increasing again since then. The large decrease in import volume in 1985 was due to the expansion of Esso's refinery. By product, diesel oil shows the greatest increase in both volume and growth rate. In 1989, 4.3 million kiloliters of diesel oil were imported; this accounted for as much as 68 percent of the total imports of petroleum products. The domestic production of diesel oil supplied only 48 percent. LPG imports did not increase as quickly as the demand for it grew, because more LPG was separated from the domestic natural gas. The degree of LPG self-sufficiency was lowest at 27 percent in 1983; however, it rapidly increased to 77 percent in 1985 with the realization of full-scale operation of the gas separation plant and the expansion of Esso's refinery. Imports of aviation fuel increased as the number of passenger flights increased to meet the boom in tourism. The declining demand for gasoline caused a decline in imports. A small amount of surplus gasoline was exported in 1984; however, the improving economy has increased both consumption and imports since 1987. The decrease in imports of fuel oil after peaking in 1983 was brought about by substitution by natural gas. Kerosene has been overproduced since 1987, but it has not been exported.

Thailand imports petroleum products more from Singapore than from any other country. From Middle Eastern countries, Thailand imports almost nothing except LPG. In 1989, Thailand imported 96 percent of its diesel oil, 96 percent of its aviation fuel, 99 percent of its gasoline, and 16 percent of its LPG from Singapore. Other than Singapore, the sources of LPG were Saudi Arabia 49 percent, UAE 13 percent, Indonesia 11 percent, Malaysia 9 percent, and the Philippines 2 percent.

4) Prices

In Thailand, the government controls the prices of petroleum products: ex-refinery prices, wholesale prices and retail prices. Different retail prices are set for the Bangkok metropolitan area and for other areas. Table 4-16 shows the retail prices in the Bangkok metropolitan area. Generally, the prices of petroleum products have been falling, influenced by the decline in the price of crude oil in the international

market.

Table 4-16 Retail Prices of Petroleum Products in Bangkok

(Unit: Bahts/Liter)

Petroleum Products	1983 Dec.	1985 Dec.	1986 Jul.	1987 Aug.	1988 Nov.	1989 Sep.13	1989 Sep.26
LPG(Baht/kg)	9.46	9.46	9.46	9.85	9.85	10.40	11.05
Premium Gasoline	11.70	11.70	8.90	8.90	8.45	8.75	11.05
Regular Gasoline	10.80	10.80	8.20	8.20	7.75	8.05	10.35
Kerosene	6.12	6.12	6.12	6.12	6.12	6.42	8.72
High Speed Diesel	6.70	6.70	6.30	6.30	6.10	6.40	8.40
Low Speed Diesel	6.50	6.50	6.10	6.10	5.90	6.20	8.20
Fuel Oil							
Viscosity 600 Second	4.32	4.32	3.23	3.12	3.02	3.32	4.25
Viscosity 1500 Second	4.17	4.17	2.91	3.03	2.93	3.20	3.90
Viscosity 2000 Second	4.04	4.04	2.69	2.97	2.87	3.17	3.81
Viscosity 2500 Second	3.99	3.99	2.58	2.58	2.84	3.14	3.72

Source: Oil and Thailand, NEA
Siam Business News No.277

The tax rates on petroleum products as of the end of December 1989 are given below. Gasoline is heavily taxed.

Gasoline:	3.3330 bahts/liter
Kerosene:	2.6765 bahts/liter
Diesel Oil:	2.3230 bahts/liter
Heavy Oil:	0.2020 bahts/liter

(5) Electricity

1) Power Generation Facilities and Production

In Thailand, the following three public corporations are engaged in the generation and distribution of electricity: the Electricity Generating Authority (EGAT), the Metropolitan Electricity Authority (MEA), and the Provincial Electricity Authority (PEA). EGAT owns most of the power generation facilities in Thailand. EGAT is in charge of generation and transmission to the primary substations. EGAT also deals with Malaysia and Laos for imports and exports of electricity. MEA and PEA receive power from EGAT and handle the downstream distribution; MEA covers the three provinces in the metropolitan area and PEA the other 69

provinces. Large consumers like Siam Cement or the TORC Refinery receive power directly from EGAT.

The power generation facilities in Thailand are owned almost exclusively by EGAT, as stated previously; however, PEA had a diesel generation plant of 55MW as of 1988, while NEA also has small facilities for hydro power generation. Some large factories and plants have their own independent generators, but their share in the total generating capacity is small. Table 4-17 shows the installed generating capacity by type of power plant, excluding the independent power plants, and Table 4-18 shows the electric power generation.

Table 4-17 Installed Generating Capacity by Types of Power Plant
(Unit: MW)

	Hydro	Steam	Gas Turbine	Diesel	Combined Cycle	Total
1979	910	1,778	165	110	--	2,963
1980	1,270	1,778	285	115	--	3,448
1981	1,361	1,928	610	109	--	4,008
1982	1,519	1,928	490	106	360	4,403
1983	1,501	2,477	250	84	720	5,032
1984	1,714	3,327	265	102	720	6,128
1985	2,004	3,628	265	88	720	6,705
1986	2,096	3,608	265	96	720	6,785
1987	2,256	3,608	267	82	772	6,985
1988	2,268	3,608	267	82	772	6,956
1989	2,271	3,982	267	74	772	7,366

Source: Electric Power in Thailand, NEA

The installed generating capacity increased 2.5 times during the decade from 1979 to 1989 from 2,963MW to 7,366MW at a high rate of 10 percent per year on average. The ratio of installed capacity by type in 1989 was: 54 percent by steam, 30 percent by hydro power, 11 percent by combined cycle, 4 percent by gas turbine, and 1 percent by diesel. The main facilities are the Bang Pakong Power Plant with 1,872MW, consisting of 1,100MW of steam and 772MW combined cycle, and the South Bangkok Power Plant with 1,300MW. They use both fuel oil and natural gas. They are both located in the metropolitan area and near Rayong where the submarine natural gas pipeline lands. The Bang Pakong power plant is the first power plant with the combined cycle system among the ASEAN.

Table 4-18 Electricity Generation by Types of Power Plant

(Unit: GWh)

	Hydro	Steam	Gas Turbine	Diesel	Combined Cycle	Total
1979	3,263	9,773	260	146	--	13,443
1980	1,273	12,762	259	131	--	14,426
1981	2,974	11,973	383	47	--	15,377
1982	3,837	11,907	847	24	5	16,620
1983	3,660	12,078	163	38	2,918	18,857
1984	4,081	14,703	346	21	1,872	21,025
1985	3,692	16,935	55	419	1,874	23,074
1986	5,554	16,083	706	25	2,348	24,717
1987	4,075	20,508	755	65	3,250	28,652
1988	3,779	22,967	764	21	4,934	32,464
1989	5,571	25,961	786	10	5,078	37,406

Source: Electric Power in Thailand, NEA

Thermal power generation plants for burning lignite are located in Mae Moh and Krabi, near coal mines. Their installed capacities are 825MW and 40MW, respectively. The major hydro power stations are the Bhumibol Plant with 535MW, the Sirikit Plant with 375MW, the Srinagarind Plant with 540MW, the Rajjaprabha Plant with 240MW, and the Khao Laem Plant with 300MW. A nuclear power station is now under study.

The total generation of electricity in Thailand was 37,406GWh in 1989. The ratios by source were: 51.3 percent by natural gas, 21.1 percent by lignite, 14.9 percent by hydro power, and 12.7 percent by fuel oil and diesel oil. Table 4-19 shows electric power generation by energy source. As is obvious from the table, the consumption of oil has been decreasing sharply, while the utilization of natural gas and lignite has increased. The reasons for the rapid diversification of fuels for power generation are that the utilization of lignite has been promoted since the energy crisis, and that natural gas was developed and made available for power generation.

In 1989, about 60 percent of the total electricity generated was in Central Region including Bangkok, mainly by thermal power generation, a little less than 30 percent in Northern Region, mainly by lignite burning and hydro power plants, about 5 percent in Southern Region and one percent in Northeastern Region, the latter two regions mainly

by hydro power.

Table 4-19 Electricity Generation by Energy Sources

(Unit: GWh)

	1979	1983	1984	1985	1986	1987	1988	1989
Hydro	3,263	3,660	4,081	3,692	5,594	4,075	3,779	5,571
Fuel Oil	8,500	7,099	6,335	3,380	3,332	2,188	3,142	4,739
Diesel Oil	406	124	28	24	34	67	24	23
Lignite	1,273	1,804	2,317	5,313	5,545	6,698	6,800	7,879
Natural Gas	--	6,169	8,263	10,666	10,252	15,624	18,720	19,195
Total	13,443	18,857	21,025	23,074	24,717	28,652	32,464	37,406

Source: Electric Power in Thailand, NEA

The unused capacity rate at peak generation increased from 26 percent in 1979 to 43 percent in 1985. The rate decreased to 16 percent in 1989 as industrialization and the modernization of lifestyles took place very rapidly.

Net imports of electricity in 1989 were 620GWh, with imports of 643GWh and exports of 23GWh.

2) Consumption of Electricity

The expansion of facilities and the increase in generation mentioned above naturally reflected the increase in the demand for electricity. The consumption of electricity by consumer is summarized in Table 4-20.

The consumption of electricity increased from 12,434GWh in 1979 to 32,834GWh in 1989 at an average rate of 10.2 percent per year. The residential and commercial sector, including street lighting, showed a 10.6 percent increase, a rate exceeding the growth of industrial use at 10.0 percent. Such a fast growth in residential and commercial use is accounted for by the increase in demand in rural areas stimulated by the extension of facilities for transmission and distribution to remote areas.

During this period, the demand increased at an average rate of 7.7 percent in the metropolitan area covered by MEA; the growth rates in Northern, Northeastern, Central and Southern Regions covered by PEA

were 15.5, 13.2, 13.3 and 11.4 percent, respectively.

Table 4-20 Electricity Consumption by Consumers

(Unit: GWh)

	1979	1983	1984	1985	1986	1987	1988	1989
Residential	2,738	4,188	4,732	5,165	5,795	6,136	6,254	7,025
Commercial [1/]	3,617	4,530	4,913	5,344	5,848	7,331	8,848	10,108
Industry	5,969	8,014	8,724	9,298	10,163	11,319	12,952	15,431
Agriculture	17	41	48	55	57	61	67	90
Street Lighting	73	103	118	128	141	--	--	--
Others	20	31	39	42	31	47	132	180
Total	12,434	16,906	18,572	20,032	22,034	24,894	28,253	32,834

Note: [1/] Including street lighting since 1987
Source: Electric Power in Thailand, NEA

3) Prices of Electricity

The prices of electricity in Thailand are prescribed by one unit price table throughout the country irrespective of whether MEA or PEA presides. The average unit price is low in rural areas where consumption per family is small, but high in the Bangkok metropolitan area. This is because the price of household electricity is divided into 10 grades, and the unit prices increase progressively as consumption increases based on the concept of the civil minimum cost.

The prices of electricity for business and industrial uses are divided into large users and small users depending on the maximum indication of the electric current meters. For the purpose of promoting industrial investments, preferential treatment for industrial complexes and discounts according to fluctuations in the oil price are provided. Electricity is supplied generally by MEA or PEA irrespective of the scale of the contract supplies, although some special consumers like key industries and broadcasting companies are supplied directly by EGAT, and their prices are determined on a case-by-case basis.

Table 4-21 shows the average unit prices of electricity. The prices were increased consecutively in 1981 and 1982, and these price hikes reflected themselves in the average price. The prices were lowered in 1983 to follow the decline in the price of crude oil.

Table 4-21 Average Unit Price of Electricity Sold

(Unit: Bahts/kWh)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Residential										
MEA	1.29	1.77	1.78	1.77	1.78	1.77	1.78	1.77	1.75	1.77
PEA	1.14	1.47	1.48	1.47	1.46	1.46	1.42	1.41	1.37	1.37
Commercial										
MEA	1.24	2.04	2.14	2.11	2.10	2.10	2.10	2.05	2.02	1.99
PEA	1.33	1.99	2.10	1.93	2.00	1.92	1.88	1.90	1.96	1.92
Industrial										
MEA	1.04	1.62	1.71	1.68	1.68	1.69	1.68	1.62	1.59	1.58
PEA	1.13	1.66	1.75	1.66	1.63	1.64	1.77	1.56	1.54	1.54
Agriculture										
MEA	--	--	--	--	--	--	--	--	--	--
PEA	0.73	1.06	1.12	1.14	1.17	1.17	1.17	1.18	1.18	1.17
Street Lighting										
MEA	0.79	1.39	1.44	1.41	1.40	1.39	1.38	0.57	--	--
PEA	0.86	1.34	1.77	1.21	1.11	1.25	1.16	1.17	--	--
Others										
MEA	--	--	--	--	--	--	--	--	--	--
PEA	1.61	2.73	3.31	3.28	3.21	3.01	3.15	2.74	2.11	2.34
Total										
MEA	1.15	1.77	1.86	1.84	1.84	1.85	1.85	1.81	1.78	1.77
PEA	1.17	1.16	1.73	1.65	1.65	1.63	1.68	1.60	1.60	1.59

Source: Electric Power in Thailand, NEA

4-2-2 Non-commercial Energy

(1) Charcoal and Firewood

Charcoal and firewood supplies have remained almost unchanged, as indicated by Table 4-22. About 30 percent of the wood for fuel is consumed as firewood, and the rest is processed into charcoal. The rate of conversion of wood into charcoal is low at about 44 percent on a thermal basis. About 80 percent of the firewood and almost all the charcoal are consumed for household and commercial uses. Industrial consumption is limited.

The consumptions of charcoal and firewood in rural areas in 1988 are compared with those for the whole kingdom and summarized in Table 4-23. The table shows that the rural areas consumed 77 percent of the firewood and 87 percent of the charcoal consumed in the whole kingdom, or 91 percent of the firewood and 84 percent of the charcoal consumed

by the residential and commercial sector only. In rural areas, the total energy consumption was 6,432 KTOE, of which charcoal and firewood together accounted for 62 percent, or firewood 34 percent and charcoal 28 percent. These figures explain the importance of wood fuel in rural areas.

Table 4-22 Supply of Firewood and Charcoal

(Unit: KTOE)

	1982	1983	1984	1985	1986	1987	1988	1989
Firewood								
Supply	8,953	8,902	8,899	8,861	8,753	8,717	8,555	8,506
Conversion	6,277	6,162	6,063	5,986	5,868	5,874	5,730	5,698
Net Supply	2,676	2,740	2,837	2,875	2,885	2,835	2,825	2,798
Consumption								
Residential [1/]	2,169	2,189	2,237	2,294	2,313	2,270	2,267	2,241
Manufacturing	597	551	600	581	572	565	558	557
Total	2,676	2,740	2,837	2,875	2,313	2,835	2,825	2,798
Charcoal								
Supply	2,227	2,183	2,161	2,138	2,103	2,103	2,066	2,008
Consumption								
Residential [1/]	2,227	2,183	2,161	2,138	2,103	2,103	2,066	2,008
Manufacturing	0	0	0	0	0	0	0	0
Total	2,227	2,183	2,161	2,138	2,103	2,103	2,066	2,008

Note: [1/] Residential and Commercial Sector
Source: Thailand Energy Situation, NEA

Table 4-23 Firewood & Charcoal Consumption by Area (1988)

(Unit: KTOE)

	Firewood	Charcoal	Total
Rural Area			
Residential & Commercial	2,070	1,741	3,811
Manufacturing	100	55	155
Total	2,170	1,796	3,966
Whole Kingdom			
Residential & Commercial	2,267	2,066	4,333
Manufacturing	558	0	588
Total	2,825	2,066	4,891

Source: Thailand Energy Situation 1988, NEA

Charcoal and firewood are still very important energy sources in rural areas, and will continue to be so in the future unless an appropriate substitute is supplied at a low price. Waste wood from saw mills or

demolished buildings, as well as old rubber trees, are used for charcoal production in addition to live trees cut down for the purpose of charcoal production. Seriously enough, the current volume of trees cut down for the purpose of firewood and charcoal production already exceeds the sustainable supply from the existing forests. The gap between the wood actually cut and the sustainable supply will become larger as the population increases in rural areas and the forest area diminishes.

The distribution system of charcoal is very complicated, varying from one place to another. The main supply sources of charcoal to Bangkok are the forests to the east and west of Bangkok, the mangrove woods along the west coast of the Malay Peninsula and the rubber plantations in Southern Region. There are many producers and dealers of charcoal in these areas. Charcoal is transported by truck; the producers usually bear the cost of transportation to Bangkok. In rural areas, charcoal is usually supplied from neighboring forests. It is not uncommon that consumers produce charcoal for their own consumption. The structure of the distribution channel varies with place and market size; in some areas, the producers sell charcoal, while in others, middlemen exist. The price of charcoal varies depending on the material and the size of one pack, as well as reflecting the complexity of the distribution system. In Bangkok, the price of charcoal increased twofold after the cutting down of forest trees was prohibited in 1988.

(2) Rice Husks

Rice husks are produced as a by-product of rice, the most important agricultural product of Thailand. Besides being used as boiler fuel in rice mills, rice husks are used as fuel for backyard charcoal production, household fuel, and fuel for small- and medium-scale industries. As firewood is becoming more difficult to acquire, firewood is being replaced by commercial energy such as fuel oil and gas for industrial uses; rice husks are also finding an increasing number of outlets as substitutes for firewood in industries like brickyards. Besides being used as fuel, rice husks are blended in certain raw materials for bricks or ceramics.

Generally, the yields of rice husks are 10 to 15 percent per paddy. In 1989, the production of rice husks in Thailand is estimated at 2 to 3 million tons based on the production of rice of about 20 million tons. Table 4-24 shows the production of paddy and rice husks, their uses and utilization rate from 1982 to 1989.

Like other biomass, although there are no reliable statistics on the production and consumption of rice husks, it is estimated that their utilization rate is rather high as the table shows.

Table 4-24 Production and Consumption of Paddy and Rice Husks

(Unit: Thousand Tons)

	1982	1985	1986	1987	1988	1989
Paddy Production/1	17,200	20,599	19,026	17,072	20,882	21,400
Paddy Husks Product'n/2	2,457	2,943	2,718	2,439	2,983	3,057
Paddy Husks Consumpt'n/3						
Manufacturing	1,352	1,710	1,715	1,548	1,356	1,812
Residential & Commercial	289	726	745	765	783	780
Total	1,641	2,436	2,460	2,313	2,139	2,592
Utilization Rate,%	67	83	91	95	72	85

Source: /1 Ministry of Agriculture and Co-operatives
/2 Mission's Estimation
/3 Thailand Energy Situation, NEA

(3) Bagasse

Bagasse is a by-product of sugar from sugarcane. It is considered that in Thailand about 300 kilograms of bagasse is produced from one ton of sugarcane. It is estimated therefore that in 1989 about 10 million tons of bagasse were produced from 33.6 million tons of sugarcane. Bagasse is used mainly as fuel for the boilers of sugar mills. Table 4-25 shows the production of sugarcane and bagasse, and the consumption and utilization rate of bagasse from 1982 to 1989.

Generally, a sugar mill consumes 75 percent of its own bagasse production as boiler fuel and leaves 25 percent as surplus. Some mills in Thailand use supplementary fuel like fuel oil because their bagasse contains more water than those of other countries and does not burn well. If the entire quantity of bagasse shown in Table 4-25 is consumed

in sugar mills, it would mean that the sugar industry in Thailand has room for energy saving.

Thai bagasse has uses other than that of fuel; a raw material for paper, for example. Therefore, in Thailand, it is considered that the entire supply of bagasse available is effectively utilized.

Table 4-25 Production and Consumption of Bagasse

(Unit: Thousand Tons)

	1984	1985	1986	1987	1988	1989
Sugar Cane Production/1	25,053	24,000	24,441	27,200	36,670	33,560
Bagasse Production/2	7,516	7,200	7,332	8,160	11,001	10,068
Bagasse Consumption/3	6,235	6,835	6,899	6,861	7,202	10,590
Utilization Rate,%	83	95	94	84	65	105

Source: /1 Ministry of Agriculture and Co-operatives
/2 Mission's Estimation
/3 NEA Thailand Energy Situation

Note: The incompatibility between the bagasse production and bagasse consumption for 1989 arising from the difference in the sources of information is not reconciled.

4-2-3 Others

(1) Oil Shale

Thailand is one of the world's richest countries in terms of oil shale. Its oil shale reserve is 18.5 billion tons. The largest deposit is located in Mae Sot which has a reserve of about 18.0 billion tons. The average oil content is reportedly 5 percent, or 13.2 gallons per ton. There were some preliminary surveys carried out in the past on the utilization of oil shale. One of them studied the feasibility of using the ash left after burning oil shale as a raw material for cement production. The Fifth Five-year Plan recommended the construction of a 4,000 barrel-per-day extraction plant to utilize low-quality oil shale. However, oil shale has not been utilized yet due to an environment where weak oil prices have prevailed.

(2) Nuclear Energy

Thailand does not have a nuclear power plant, and the plans announced by EGAT for the year 2000 do not include a nuclear plant.

(3) New Energy

In Thailand, the utilization of solar energy, various kinds of biomass and non-conventional energy has been studied and promoted. However, the main purpose is to provide energy in remote rural areas so as to raise the standard of living where the supply of conventional energy including electricity is costly. In other words, the utilization of non-conventional energy will be focused on remote sparsely populated areas. Therefore, the contribution of non-conventional energy to total energy consumption in the whole kingdom will not be substantial.

4-3 Energy Consumption by Sector

4-3-1 Energy Consumption in the Residential and Commercial Sector

(1) Outline

The terms, residential and commercial uses, are used to mean that the former indicates household use and the latter includes a variety of users such as shops, restaurants, hotels, offices, hospitals, schools, and the like. Energy consumption in these two categories is treated as one.

Table 4-26 summarizes the energy consumption in the residential and commercial sector by type of energy. The consumption increased from 5,502 KTOE in 1982 to 6,889 KTOE in 1989 at an average rate of 3.3 percent per year. Energy consumption per capita increased from 112.6 KGOE in 1982 to 123.3 KGOE in 1989. By type of energy, charcoal and firewood consumption overwhelms all others. The share of wood fuel in the total consumption in 1989 was 61 percent, 32 percent for firewood and 29 percent for charcoal. The consumption of both charcoal and firewood remained nearly constant, although their consumption per

capita showed a continuing decrease. From 1982 to 1989, the consumption of firewood per capita decreased at an average rate of 1.4 percent per year and that of charcoal at 3.4 percent. The consumptions of LPG and electricity both increased. LPG consumption in the same period increased at an average rate of 22.0 percent per year, or at 19.5 percent per year per capita. The rate of electricity consumption was 12.7 percent, or 10.5 percent per year per capita. Unlike others, the consumption of kerosene alone declined substantially, because the consumption for lighting, the main use of kerosene, decreased with the spread of electrification.

Table 4-26 Energy Consumption in the Residential and Commercial Sector

	1982	1983	1984	1985	1986	1987	1988	1989
Total Consumption(KTOE)								
LPG	199	230	232	367	454	541	687	801
Kerosene	154	139	124	82	73	64	62	58
Diesel	10	2	1	1	3	1	0	1
Fuel Oil	6	5	4	5	11	17	14	39
Electricity	638	743	822	895	992	1,136	1,287	1,475
Firewood	2,169	2,189	2,237	2,294	2,313	2,270	2,267	2,241
Charcoal	2,227	2,183	2,161	2,138	2,103	2,103	2,066	2,008
Paddy Husks	99	131	179	247	254	261	267	266
Total	5,502	5,622	5,760	6,029	6,203	6,393	6,650	6,889
Per Capita Consumption(KGOE)								
LPG	4.1	4.7	4.6	7.1	8.6	10.0	12.5	14.3
Kerosene	3.2	2.8	2.5	1.6	1.4	1.2	1.1	1.0
Diesel	0.2	0.1	0.0	0.0	0.1	0.0	0.0	0.0
Fuel Oil	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.7
Electricity	13.1	15.1	16.3	17.3	18.7	21.1	23.4	26.4
Firewood	44.4	44.3	44.2	44.3	43.7	42.1	41.2	40.1
Charcoal	45.6	44.2	42.7	41.3	39.7	39.0	37.6	35.9
Paddy Husks	2.0	2.7	3.5	4.8	4.8	4.8	4.9	4.8
Total	112.6	113.7	113.9	116.4	117.1	118.7	121.0	123.3

Source: Thailand Energy Situation, NEA

The consumption of LPG and electricity was increasing, while the consumption of wood fuel remained constant for the following reasons: (1) Both deforestation and restrictions on the cutting down of trees made the supply of wood fuel more difficult. (2) The supply systems of more convenient LPG and electricity were becoming well organized and extended.

(2) Energy Consumption by Use and Income Level

In the residential and commercial sector, energy is used mostly for cooking and lighting; other uses include power for electric appliances like air conditioners or television sets, water pumping, and small-scale household industries. Cooking consumed the most among them and is estimated to have consumed 77 percent of the total residential and commercial energy consumption of 1989. The energy consumption for cooking is calculated using the following procedures on the basis of Table 4-26.

(1) Charcoal, firewood and rice husks are regarded as being used entirely for cooking because other uses are very limited.
(2) The use of LPG for privately-owned cars is so little that all LPG is regarded as cooking fuel.
(3) The consumption of electricity by rice-cookers is so small that it is regarded as nought.
(4) Kerosene is used for lighting only.
(5) Fuel oil is ignored because the consumption is so negligibly small, while fuel oil is consumed by a variety of commercial users other than in cooking, hotels, for instance.

An estimate of the energy consumption for cooking based on the above premises is summarized in Table 4-27.

Consumption for uses other than cooking in this sector is estimated at 10 percent for lighting, 3 percent for air conditioning, and 7 percent for others. These ratios and type of energy vary greatly depending on household income. Specifically, the higher the income a family has, the lower the ratio of energy consumption for cooking and the ratio of non-commercial energy like charcoal and firewood are, and the higher the ratio of commercial energy like LPG and electricity is. Table 4-28 shows the monthly energy consumption per family by income. Please note that these figures were arrived at by the study team based on information from the National Statistical Office, and they do not necessarily agree with the figures in Table 4-27 taken from the statistics of NEA. It may be noted from Table 4-28 that the ratio of charcoal and

firewood to domestic energy consumption is 70 percent as the national average, 95 percent for families with a monthly income of 1,000 Bahts or less, and only 20 percent for families with a monthly income of 7,500 Bahts or more.

Table 4-27 Estimated Energy Consumption for Cooking in the Residential and Commercial Sector

(Unit: KTOE)

	1982	1983	1984	1985	1986	1987	1988	1989
Charcoal	2,227	2,183	2,161	2,138	2,103	2,103	2,066	2,008
Firewood	2,169	2,189	2,237	2,294	2,313	2,270	2,267	2,241
Paddy Husks	99	131	179	247	254	261	267	266
LPG	199	230	232	367	453	541	687	801
Electricity	nil	nil	nil	nil	nil	nil	nil	nil
Total	4,694	4,733	4,809	5,046	5,123	5,175	5,287	5,316
Per Capita (KGOE)	96.2	95.7	95.1	97.4	96.7	96.1	96.2	95.1

(3) Energy Consumption by Community

As stated above, in the residential and commercial sector, there is a general tendency for non-commercial energy like charcoal and firewood to be replaced by commercial energy like LPG and electricity. However, there are significant differences between urban areas as represented by Bangkok and rural areas. Table 4-29 shows the energy consumption by community type.

There is little difference in the total amount of energy consumed per capita among communities; however, there are noticeable differences in the type of energy. The share of charcoal and firewood is 40 percent in urban areas, 70 percent for the whole kingdom, and 80 percent in rural areas. The dependence on wood fuel is still very high, especially in rural areas. The share of LPG is 1.5 percent for the whole kingdom, 3.7 percent in urban areas, and 0.7 percent in rural areas, respectively. The consumption of kerosene is high in rural areas in sharp contrast to that of electricity.

Table 4-28 Average Monthly Fuel Consumption per Household by Current Monthly Income (1986)

(Unit: KGOE)

Income(B/Month)	Average	less than 499	500/ 999	1,000/ 1,999	2,000/ 2,999	3,000/ 3,499	3,500/ 4,999	5,000/ 7,499	7,500 plus
Households(%)	100.0	1.7	10.7	29.9	19.3	6.4	12.6	10.2	9.2
Av. Household Size	4.3	2.9	3.6	4.2	4.5	4.4	4.4	4.4	4.8
Commercial Energy									
Gasoline	5.26	0.17	0.43	1.16	2.14	3.67	4.58	7.44	25.95
	(14.86)	(0.73)	(1.41)	(3.49)	(5.90)	(10.82)	(13.12)	(20.79)	(42.66)
Diesel Oil	1.03	0.41	0.09	0.26	0.56	0.55	0.99	1.51	5.62
	(2.76)	(1.76)	(0.30)	(0.78)	(1.54)	(1.62)	(2.84)	(4.22)	(9.24)
Kerosene	0.57	0.01	0.04	0.06	0.08	0.15	0.17	0.35	0.66
	(1.53)	(0.04)	(0.13)	(0.18)	(0.22)	(0.44)	(0.49)	(0.98)	(1.08)
LPG	0.57	0.03	0.03	0.06	0.17	0.34	0.64	1.25	2.98
	(1.53)	(0.13)	(0.10)	(0.18)	(0.47)	(1.00)	(1.83)	(3.49)	(4.90)
Electricity	3.61	0.61	0.87	1.49	2.34	3.08	4.46	6.84	12.53
	(9.67)	(2.62)	(2.84)	(4.49)	(6.45)	(9.08)	(12.77)	(19.11)	(20.60)
Sub-total	11.04	1.23	1.46	3.03	5.29	7.79	10.84	17.39	47.74
	(29.57)	(5.29)	(4.77)	(9.12)	(14.58)	(22.96)	(31.04)	(48.56)	(78.48)
Non-Commercial Energy									
Charcoal	14.73	10.39	11.86	15.18	17.35	16.64	16.17	13.20	10.23
	(39.45)	(44.67)	(38.78)	(45.71)	(47.82)	(49.04)	(46.31)	(36.88)	(16.82)
Firewood	11.57	11.64	17.26	15.00	13.64	9.50	7.91	5.20	2.86
	(30.99)	(50.04)	(56.44)	(45.17)	(37.60)	(28.00)	(22.65)	(14.53)	(4.70)
Sub-total	26.30	22.03	29.12	30.18	30.99	26.14	24.08	18.40	13.09
	(70.43)	(94.71)	(95.23)	(90.88)	(85.42)	(77.04)	(68.96)	(51.41)	(21.52)
Total	37.34	23.26	30.58	33.21	36.28	33.93	34.92	35.79	60.83

Note: Figures in parentheses are in percentage.
Source: Energy Consumption Survey, NSO

Table 4-29 Average Monthly Fuel Consumption by Community Type (1986)
(Unit: KGOE)

	Whole Kingdom	Municipal	Sanitary	Villages
Average Household Size	4.3	3.8	4.1	4.5
Commercial Energy				
Gasoline	5.20	10.39	6.04	3.40
	(13.95)	(28.31)	(16.89)	(8.82)
Diesel Oil	1.03	2.39	1.65	0.80
	(2.76)	(6.51)	(4.61)	(2.07)
Kerosene	0.57	0.12	0.25	0.75
	(1.53)	(0.33)	(0.70)	(1.94)
LPG	0.57	1.36	0.75	0.26
	(1.53)	(3.71)	(2.10)	(0.67)
Electricity	3.61	7.57	4.46	2.04
	(9.68)	(20.63)	(12.47)	(5.29)
Sub-total	10.98	21.83	13.15	7.25
	(29.45)	(59.48)	(36.77)	(18.80)
Non-Commercial Energy				
Charcoal	14.73	11.66	14.81	16.84
	(39.51)	(31.77)	(41.41)	(43.66)
Firewood	11.57	3.21	7.80	14.48
	(31.04)	(8.75)	(21.81)	(37.54)
Sub-total	26.30	14.87	22.61	31.32
	(70.55)	(40.52)	(63.23)	(81.20)
Total	37.28	36.70	35.76	38.57

Note: Figures in parentheses are in percentage.
Source: NSO Energy Consumption Survey

4-3-2 Energy Consumption in the Manufacturing Sector

(1) Outline

In 1979, the manufacturing sector consumed 4,515 KTOE, as Table 4-30 shows. The consumption decreased to 3,995 KTOE in 1980 as a result of the increase in the price of oil caused by the energy crisis. However, it increased to 4,728 KTOE in 1982 and reached 7,712 KTOE in 1989. The average annual growth rate for the period from 1982 to 1989 was 9.8 percent. The average growth rate of GDP at 1972 prices for the same period was 8.2 percent per year.

Table 4-30 Energy Consumption in the Manufacturing Sector by Energy Type

(Unit: KTOE)

	1979	1980	1981	1982	1985	1988	1989
Coal	43	59	42	101	213	240	300
	(0.9)	(1.5)	(1.0)	(2.1)	(4.1)	(4.0)	(3.9)
Lignite	53	55	70	155	233	568	882
	(1.2)	(1.4)	(1.6)	(3.3)	(4.5)	(9.4)	(10.1)
Petroleum Products	2,019	1,877	1,686	1,487	1,420	1,786	2,137
	(44.7)	(47.0)	(39.3)	(31.5)	(27.1)	(29.4)	(27.7)
Natural Gas	-	-	-	-	178	60	114
	-	-	-	-	(3.4)	(1.0)	(1.5)
Electricity	509	550	602	630	792	1,104	1,315
	(11.3)	(13.7)	(14.0)	(13.3)	(15.2)	(18.2)	(17.1)
Renewable Energy	1,891	1,454	1,893	2,355	2,383	2,304	3,064
	(41.9)	(36.4)	(44.1)	(49.8)	(45.7)	(38.0)	(39.7)
Firewood	n.a.	n.a.	n.a.	507	581	558	557
	n.a.	n.a.	n.a.	(10.7)	(11.1)	(9.2)	(7.2)
Paddy Husks	n.a.	n.a.	n.a.	461	583	462	618
	n.a.	n.a.	n.a.	(9.8)	(11.2)	(7.6)	(8.0)
Bagasse	n.a.	n.a.	n.a.	1,387	1,219	1,284	1,889
	n.a.	n.a.	n.a.	(29.3)	(23.4)	(21.2)	(24.5)
Total	4,515	3,995	4,293	4,728	5,219	6,062	7,712

Source: Thailand Energy Situation, NEA

By type of energy, the consumption of non-commercial energy is the largest, with a share of 40 percent in 1989, for example. Firewood, rice husks, bagasse and other kinds of non-commercial energy are used as boiler fuel for sugar mills and rice mills, as a heat source for the ceramic industry, as fuel for saw mills and others. Among the different types of commercial energy, petroleum products, electricity and solid fossil fuels are consumed in large amounts, representing 28, 17 and 14 percent, respectively; but the consumption of natural gas is small. The petroleum products which ranked first with a share of 44.7 percent in 1979 were decreasing and electricity was increasing instead. This means that there was a shift from petroleum products to electricity as energy used by the manufacturing sector.

Energy is consumed by various industries such as food, tobacco, non-metallic industries, textile, leather, and chemical industries including petroleum, coal, rubber and synthetic resin. The food industry consumes by far the more energy than any other industry in 1989, representing 46.0 percent of the total industrial energy consumption. In the

food industry, rice mills, sugar mills and ice manufacturing are large consumers. The non-metallic, textile and chemical industries follow the food industry with shares of 23.8, 9.5 and 6.4 percent, respectively. Table 4-31 summarizes the consumption of energy by the manufacturing sector by type for 1989.

Table 4-31 Energy Consumption in the Manufacturing Sector by Energy Type (1989)

(Unit: KTOE)

Sub-group	Coal & Lignite	Petroleum Products	Natural Gas	Elec-tricity	Renewable Energy	Total
Food	96	384	-	270	2,801	3,551
Textile	11	417	-	301	-	729
Wood	-	32	-	28	31	91
Paper	152	94	-	60	-	306
Chemical	28	146	39	188	95	496
Non-Metallic	762	674	75	187	137	1,835
Basic Metal	29	134	-	121	-	284
Fabricated Metal	-	31	-	117	-	148
Others	4	225	-	43	-	272
Total	1,082	2,137	114	1,315	3,064	7,712

Source: Thailand Energy Situation, NEA

(2) Non-commercial Energy Consumption

The non-commercial energy used in this sector is firewood, rice husks and bagasse. Charcoal is not used to any appreciable amount in the industrial sector.

1) Firewood

Firewood used to be the most important source of energy in Northern and Southern Regions where there were rich natural forests. The major industrial consumers of firewood were saw mills, tobacco curing factories, noodle-making factories, rice mills, bakeries, cement processing factories, sugar mills, sauce-making factories, flour mills, brickyards, ceramic factories and glass factories. Low-priced firewood was used in preference to commercial energy except when the quality of fuel was important. Recently, however, firewood has become so difficult to acquire because of the decrease in forest resources that some factories have changed the type of fuel and manufacturing processes they use.

Table 4-32 shows the consumption of firewood in the industrial sector.

Table 4-32 Historical Consumption of Firewood

	1982	1983	1984	1985	1986	1987	1988	1989
Consumption								
Total(KTOE)	507	551	600	581	572	527	558	557
Per Capita(KGOE)	10.4	11.1	11.9	11.2	10.8	9.8	10.1	10.0
Per GDP(KGOE/1,000B)	1.5	1.6	1.6	1.5	1.4	1.2	1.1	1.0

Source: Thailand Energy Situation, NEA

2) Others

The other important members of non-commercial energy in the industrial sector are rice husks used by rice mills, noodle-making factories, brickyards and food-processing factories, and bagasse used by sugar mills. Table 4-33 shows the historical consumption of rice husks and bagasse in the industrial sector.

Table 4-33 Historical Consumption of Paddy Husks and Bagasse

	1982	1983	1984	1985	1986	1987	1988	1989
Paddy Husks								
Total(KTOE)	461	433	563	583	584	527	462	618
Per Capita(KGOE)	9.4	8.8	11.1	11.3	11.0	9.8	8.4	11.1
Per Capita(KGOE/1,000B)	1.4	1.2	1.5	1.5	1.4	1.2	0.9	1.1
Bagasse								
Total(KTOE)	1,387	1,164	1,112	1,219	1,230	1,224	1,284	1,889
Per Capita(KGOE)	28.4	23.6	22.0	23.5	23.2	22.7	23.3	33.8
Per GDP(KGOE/1,000B)	4.2	3.3	2.9	3.1	3.0	2.7	2.6	3.3

Source: Thailand Energy Situation, NEA

(3) Commercial Energy Consumption

The commercial energy consumed in the manufacturing sector is coal, petroleum products, natural gas and electricity. The consumption trends are discussed below.

1) Coal

Coal or lignite is used in cement manufacturing and tobacco curing, as

well as in other industries in this sector. As a rule, high-quality coal is used in cement manufacturing, while the tobacco curing industry uses coal of inferior quality but not as poor as that used for power generation. Table 4-34 shows the historical consumption of coal and lignite in this sector. Compared with the lignite used for power generation, the consumption of coal in this sector grew at a much slower pace for the following reasons:

- The cement industry has to blend the Thai coal with oil or imported coal to improve the quality.
- The cost of transportation is high.
- The quality and supply are both unstable.
- The cost of converting the present fuel to coal is high.
- There are technical problems associated with storage and ash disposal.

Table 4-34 Historical Consumption of Coal in the Manufacturing Sector
(Unit: KTOE)

	1982	1983	1984	1985	1986	1987	1988	1989
Steam Coal	58	59	88	151	112	156	185	237
Anthracite	3	3	3	6	3	2	5	5
Coke	40	46	53	56	26	38	50	55
Others	0	0	0	0	0	0	0	3
Lignite	155	151	157	233	323	478	568	782
Total	256	259	301	446	464	674	808	1,082

Source: Thailand Energy Situation, NEA

2) Petroleum Products

The manufacturing sector consumes a large amount of petroleum products next only to the transportation sector; in 1989, the consumption of petroleum products was 2,137 KTOE. By kind, the consumption of fuel oil was by far the largest: 1,827 KTOE, or 85 percent of the total consumption of petroleum products in 1989. The non-metallic industries including cement manufacturing are large consumers but their share is declining. On the other hand, the textile and leather industries are rapidly increasing consumption. The food-processing and chemical industries are increasing consumption, too. Table 4-35 shows the consumption of petroleum products in this sector.

Table 4-35 Historical Consumption of Petroleum Products in Manufacturing Sector

(Unit: KTOE)

	1982	1983	1984	1985	1986	1987	1988	1989
LPG	46	68	79	90	90	84	90	94
Premium Gasoline	13	5	6	6	6	5	5	5
Regular Gasoline	25	4	3	3	2	3	3	2
Kerosene	40	27	36	38	38	37	38	38
High Speed Diesel	184	153	136	158	154	150	129	147
Low Speed Diesel	15	24	27	27	13	13	10	24
Fuel Oil	1,164	1,143	1,128	1,099	1,145	1,311	1,511	1,827
Total	1,487	1,424	1,416	1,421	1,447	1,604	1,786	2,137

Source: Thailand Energy Situation, NEA

3) Natural Gas

Cement manufacturing was Thailand's first manufacturing industry to use natural gas. Siam Cement, a large consumer, has laid a 178-kilometer pipeline for their own exclusive use in order to supply gas to two of their cement factories. Recently, the ceramic industry has also begun using natural gas. However, there is no great demand for natural gas now because of the higher price compared with that of fuel oil. Although in Thailand natural gas was used as a substitute for oil at first, it is now expected to be used as a raw material in fertilizer plants, petrochemical plants and in other industries in the future.

4) Electricity

Electricity is widely used in the manufacturing sector. This sector comes next to the residential and commercial sector in terms of consumption. The consumption of electricity in this sector increased from 7,389Gwh, or 630 KTOE in 1982 to 15,431Gwh, or 1,315 KTOE in 1989 at an average rate of 11.1 percent per year. This growth rate is not as great as the growth rates of coal and lignite for the same period, but the growth in terms of the amount of energy is the largest among all types of energy in Thailand. By type of industry, the textile and leather industry consumed 23 percent of the total electricity used in this sector, followed by food, drinks and tobacco manufacturing with a 21 percent share and the chemical, oil, coal, rubber and plastics industries with a 14 percent share.

4-4 Acts and Regulations Governing the Usage of Fuels

Reflecting the importance of energy and also a large degree of dependence on imports for the supply of commercial energy, the government exercises controls on the prices of certain products. The prices of petroleum products including LPG, price of coal used for tobacco curing and the price of electricity are under the control of the government. The installation and expansions of the refineries are also under control.

There is a ban on cutting down of trees. However, the prices of charcoal and firewood are determined by the mechanism of supply and demand. There is no law or act controlling the production, distribution and marketing of lignite briquettes. Therefore, anyone who wishes can enter into the business of manufacturing, distribution and marketing of lignite briquettes.

Perhaps, all this feasibility study would have to mind is: (1) laws and regulations concerning health and safety of the workers and pollution control which may affect the selection of the location, design and operation of the lignite briquette manufacturing plant, (2) control on the transportation by a large truck from the plant to the metropolitan areas; the transportation from north to Bangkok by a large truck is now allowed during the limited time of the day, and (3) stockpiling of lignite briquettes in a depot close to the residential area. All these are reflected in the conceptual design.

Chapter 5 Lignite Briquettes Market

Chapter 5 Lignite Briquettes Market

Lignite briquettes to be produced by this project intend to replace, in part, charcoal and firewood used in the residential and commercial sector as well as firewood used in the manufacturing sector. On the other hand, they will not be a substitute for commercial energy like petroleum products or electricity used in such other sectors as agriculture, forestry, fishery, mining, construction, and transportation, because of their distribution systems, quality, and uses being incompatible with lignite briquettes. Also, as will be explained later, it has been found that lignite briquettes will not be a substitute for firewood either for the residential and commercial sector or for the manufacturing sector. Therefore, the demands for lignite briquettes were forecast based on the forecast demands for charcoal for the household and commercial uses, as well as on the forecast degrees of substitution of charcoal by lignite briquettes.

The prices of lignite briquettes with respect to those of charcoal should affect the degree of substitution of charcoal by lignite briquettes. Therefore, opinions of the representative potential consumers were polled during the monitoring survey on the acceptability of lignite briquettes with respect to the price ratio of lignite briquettes and charcoal, and the outcomes of the monitoring survey were analyzed and used in the forecast.

5-1 Demand Forecast of Charcoal and Firewood

5-1-1 Method for Forecasting Demand for Charcoal and Firewood

(1) Forecasting Technique

The techniques for forecasting demand for a commodity may be classified broadly into three groups as follows:

1) Qualitative Method

The qualitative method is used where data is insufficient. In such a case, qualitative information is translated into quantitative values

based on the subjective judgment of experts. This method is often employed in forecasting the future of a revolutionary technology.

2) Time Series Analysis and Extrapolation of Past Data

This method uses a statistical technique and is used in a case where data are sufficiently available for some years past and where their relationships and trends are relatively definite and dependable. This method is suited for short-term forecasting, but not for long-term forecasting, because this method assumes that the trends in the future will be similar to those in the past.

3) Causal Method

It is possible to build a mathematical model linking the objective function to be forecast and the causal variables when a sufficient amount of past and present data are available, and when there exists a quantitative relationship between the objective function and these variables. These variables are often economic and relevant commercial data. Such a model is a valuable tool for forecasting because it correlates all necessary variables in a form of mathematical expression. It is also possible with this method to incorporate various kinds of market information, and at the same time, to reflect the results of the time series analyses conducted separately.

(2) Method for Forecasting Demand

Charcoal and firewood are used for cooking in the residential and commercial sector. Firewood is also used in the manufacturing sector. The causal method was used to forecast the demands for charcoal and firewood in the residential and commercial sector. The forecast firewood consumption in the manufacturing sector was then added to the results. To be more specific, a mathematical model for regression analysis was developed by means of the least-square method between the demand for energy in the residential and commercial sector and the economic indicators. With the forecast GDP separately obtained, the demand for energy was forecast. While considering the forecast demand of energy, the energy demand for cooking was estimated using the least-square method and then broken down into charcoal, firewood, and

other fuels. The forecast consumption of firewood in the manufacturing sector was added to that in the residential and commercial sector to obtain the forecast total demand for firewood.

Figures 5-1 and 5-2 show flows of the causal method for the demand forecasts. Tables 5-1 and 5-2 show the past and forecast economic indicators, respectively.

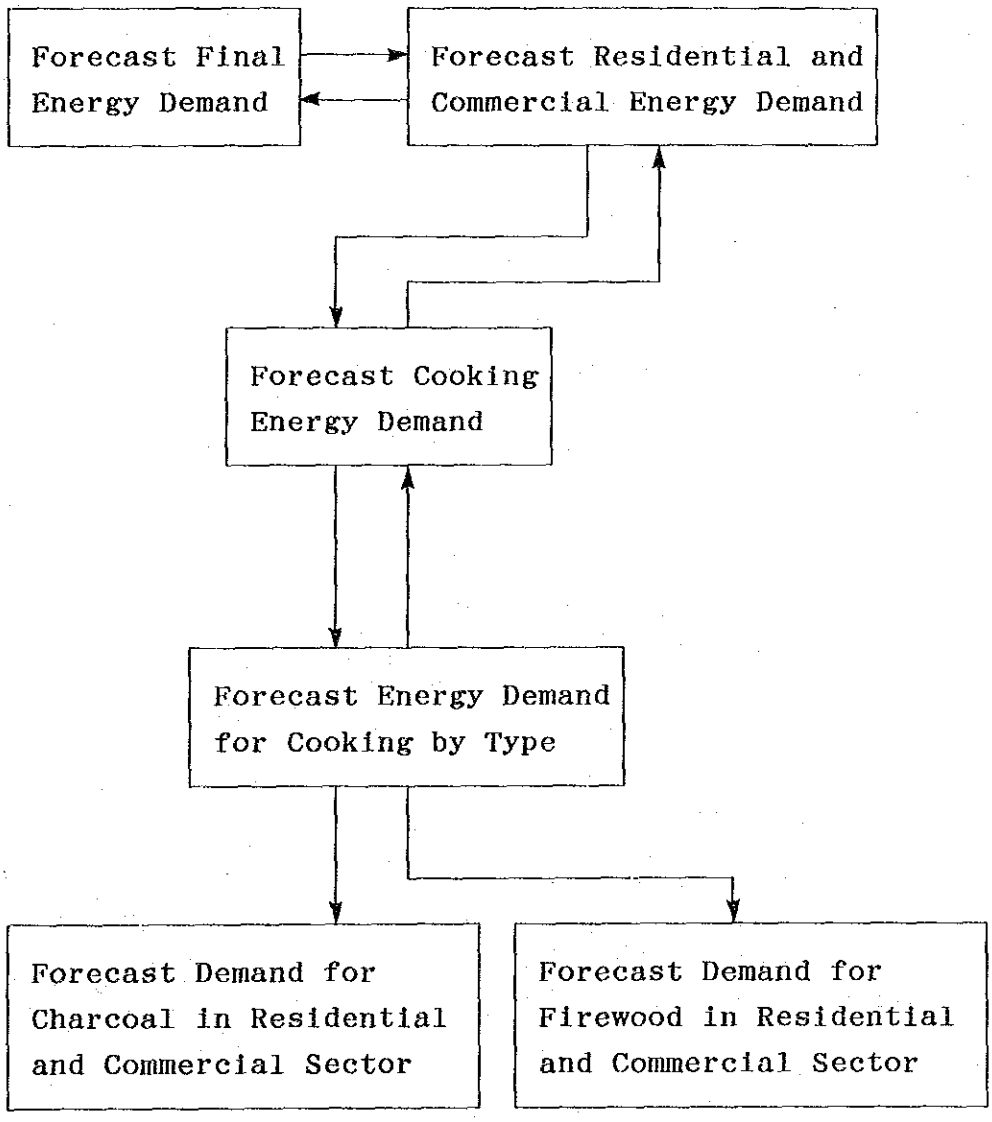

Figure 5-1 Flow of Forecasting Method (1)

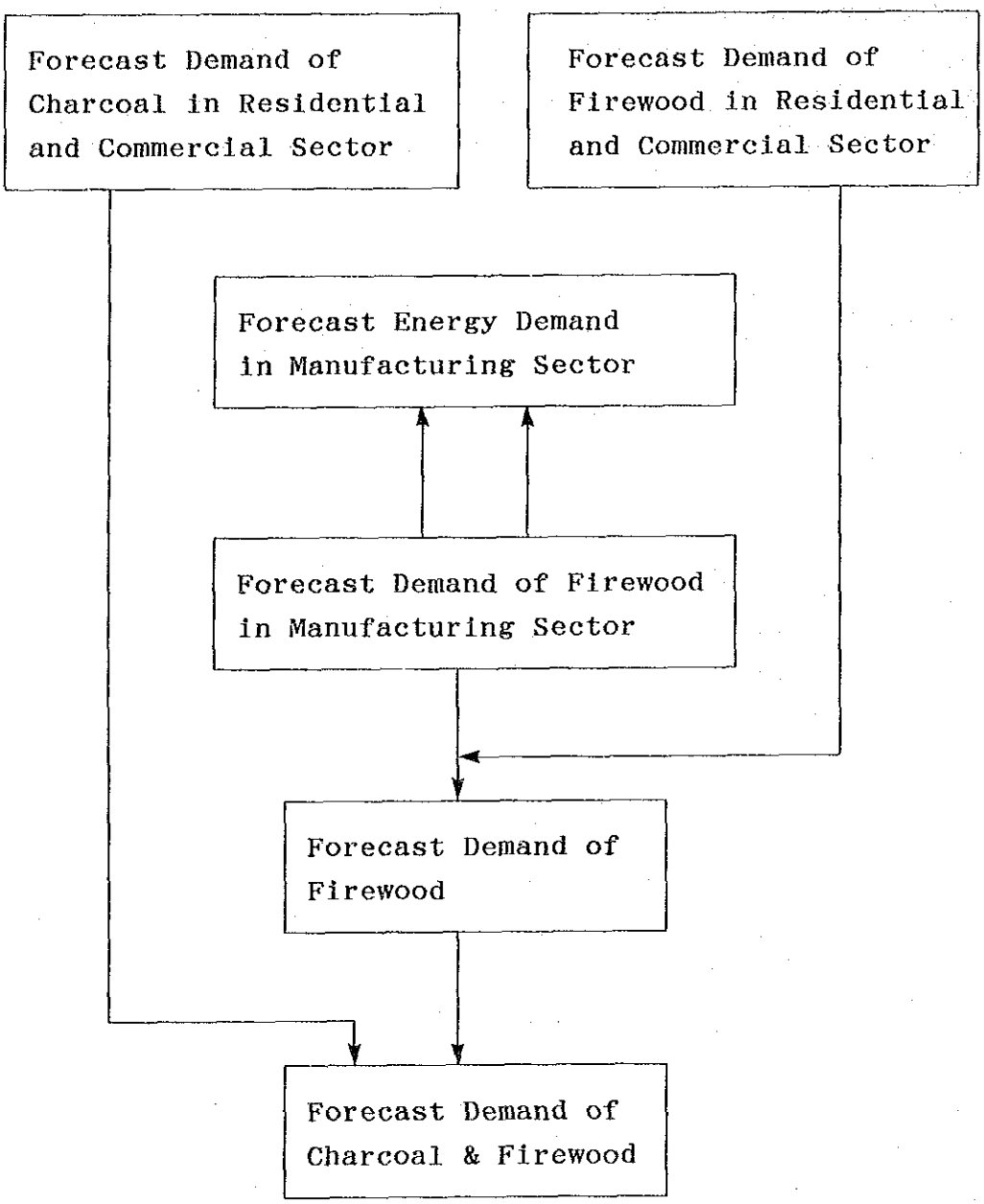

Figure 5-2 Flow of Forecasting Method (2)

Table 5-1 Historical Economic Indicator

	1972	1980	1985	Est. 1990	Growth 1980/ 1990
GDP (Billion Bahts)	164.63	658.51	1,014.40	2,052.20	12.0
GDP Deflator (1.00 as of 1972)	1.00	2.20	2.57	3.26	4.0
GDP (Billion Bahts, 1972 Price)	164.63	299.74	394.11	629.52	7.7
Population (Million)	38.59	46.72	51.68	56.10	1.9
GDP Per Capita					
(Bahts, Current Price)	4,266	14,094	19,628	36,581	10.0
(US$,Current Price)	204	683	737	1,463	7.9
GDP/Capita					
(Bahts, 1972 Price)	4,266	6,416	7,626	11,221	5.6
Exchange Rate (Bahts/US$)	20.93	20.63	26.65	25.00	-

Source: NESDB

Table 5-2 Forecast Economic Indicator

	1995	2000	2005	2010	Growth 1990/ 2000
GDP (Billion Bahts)	4,204.4	7,516.0	12,237.3	19,458.7	13.9
GDP Deflator (1.00 as of 1972)	4.31	5.49	6.68	8.13	5.4
GDP (Billion Bahts, 1972 Price)	974.9	1,368.3	1,831.1	2,393.1	8.2
Population (Million)	59.87	63.35	66.65	70.05	1.2
GDP Per Capita					
(1,000 Bahts, Current Price)	70.2	118.6	183.5	277.6	12.5
(US$,Current Price)	2,808	4,745	7,344	11,112	12.5
GDP/Capita					
(Bahts, 1972 Price)	16,284	21,600	27,473	34,163	6.8
Exchange Rate (Bahts/US$)	25.0	25.0	25.0	25.0	-

Source: Based on information and data from NESDB and The Bank of Thailand

5-1-2 Charcoal and Firewood Consumption

As stated before, forecasting the demand by the causal method requires an analysis of the data in the related fields; in the case of this study

these are economic indicators, final energy consumption, energy consumption by sector, and information and data on the consumption of charcoal and firewood. Chapter 4 presents these information and economic indicators, final energy consumption and energy consumption by sector; therefore, this section only summarizes these information and data and then proceeds to a discussion on consumption of charcoal and firewood by sector.

(1) Energy Consumption

Table 5-2 summarizes historical consumption of energy.

Table 5-3 Historical Energy Consumption

	1982	1983	1984	1985	1986	1987	1988	1989
Population(Million)	48.74	49.73	50.71	51.68	52.65	53.40	54.30	55.20
GDP 1972 Price (Billion Bahts)	331.4	355.4	380.7	394.1	413.4	452.8	512.4	574.9
GDP per Capita (Bahts)	6,799	7,147	7,507	7,626	7,852	8,479	9,436	10,415
Final Energy Consumption (KTOE)	16,221	17,022	18,272	18,856	19,556	21,048	22,927	26,775
Energy Consumption of Residential and Commercial Sector								
(KTOE)	5,502	5,622	5,760	6,029	6,203	6,393	6,650	6,889
Per Capita(KGOE)	113	113	114	117	118	120	123	125
Energy Consumption for Cooking by Residential and Commercial Sector(KTOE)								
Charcoal	2,227	2,183	2,161	2,138	2,103	2,103	2,066	2,008
Firewood	2,169	2,189	2,237	2,294	2,313	2,270	2,267	2,241
Paddy Husk	99	131	179	247	254	261	267	266
LPG	199	230	232	367	454	541	687	801
Electricity	nil	nil	nil	nil	nil	nil	nil	nil
Total	4,694	4,733	4,809	5,046	5,124	5,175	5,287	5,316
Per Capita(KGOE)	96	95	95	98	97	97	97	96
Energy Consumption of Manufacturing Sector								
(KTOE)	4,728	4,547	4,930	5,219	5,250	5,598	6,062	7,712
Firewood Consumption of Manufacturing Sector								
(KTOE)	507	551	600	581	572	581	558	557

Source: Based on the data from NEA and NESDB

Charcoal and firewood are both used as cooking fuel in the residential

and commercial sector. In addition, firewood is used as energy in the manufacturing sector. Table 5-3 shows the energy consumption in the residential and commercial sector and the consumption of firewood in the manufacturing sector along with other relevant information. The data on population and GDP are based on the statistics from the NESDB and that on energy on information from the NEA.

During the period from 1982 to 1989, population increased at a rate of 1.8 percent per year, while GDP increased at a rate of 8.2 percent, or a per-capita rate of 6.3 percent per year. This growth may be attributable greatly to the growth in the manufacturing and transportation sectors. While per-capita consumption of energy has been increasing also in the residential and commercial sector, the per-capita consumption of cooking energy has remained at about 100 kgOE.

Consumption of energy in the manufacturing sector increased at a rate of 7.2 percent per year from 4,728 KTOE in 1982 to 7,712 KTOE in 1989. The consumption of firewood in this sector had been decreasing since it peaked at 600 KTOE in 1984 to 577 KTOE in 1989, because firewood was becoming hard to come by and more expensive.

(2) Cooking Energy Consumption in the Residential and Commercial Sector

1) Charcoal

Charcoal, one of wood fuels, is used as cooking fuel in households as well as in restaurants and ready-made food vendors as a commercial fuel. Charcoal is an important fuel, particularly in rural farming areas. One problem with charcoal is that the volume of trees cut down for charcoal production has long exceeded the sustainable supply of wood from the existing forests. Concerning household consumption by area, the result of the survey indicates that the rural farming areas still consume large amounts of charcoal while the demand in urban areas is decreasing as consumption of the commercial energy, LPG for example, increases. In the urban areas, however, people tend more to eat out than in the rural areas. Therefore, the consumption of charcoal for commercial use tends to be large. Charcoal constitutes about

40 percent of cooking energy demand in rural farming areas, but the demand for charcoal has been decreasing in urban areas every year because of the replacement of charcoal by other forms of energy. Table 5-4 shows the historical consumption of charcoal for the residential and commercial sector.

Table 5-4 Consumption of Charcoal in Residential & Commercial Sector

	1981	1983	1984	1985	1986	1987	1988	1989
KTon	3,275	3,193	3,160	3,128	3,075	3,076	3,022	2,937
KTOE	2,227	2,183	2,161	2,138	2,103	2,103	2,066	2,008
Kg/Capita	67	64	62	61	58	58	56	53
KGOE/Capita	46	44	43	41	40	39	38	36
KGOE/GDP(1972) (KGOE/1,000B)	6.7	6.1	5.7	5.4	5.1	4.6	4.0	3.5

Source: Thailand Energy Situation, NEA

2) Firewood

Firewood, another wood fuel, has long been used as cooking fuel. The consumption of firewood has been decreasing because of consumers' preference for cleaner and more convenient fuels such as LPG and electricity. Firewood generates smoke and soot which stains the surroundings and tarnishes the cooking utensils necessitating tedious cleaning. Deforestation has also restrained the consumption. However, rural farming societies, especially in Northern, Northeastern, and Southern Regions, still depend mainly on firewood for cooking because of its ready availability and low prices. In 1989, the consumption of firewood for residential and commercial use was 2,241 KTOE. Firewood accounted for 8.4 percent of the total energy consumption and had the largest share of 32.5 percent in the residential and commercial sector.

In rural farming areas firewood is consumed in large amounts while the shares of charcoal and LPG are increasing in urban areas. The demand for firewood has decreased as the economy and the standard of living has improved in Thailand. Table 5-5 shows the historical consumption of firewood.

Table 5-5 Historical Consumption of Firewood

	1982	1983	1984	1985	1986	1987	1988	1989
KTon	5,732	5,784	5,911	6,062	6,112	5,997	5,990	5,921
KTOE	2,169	2,189	2,237	2,294	2,313	2,270	2,267	2,241
Kg/Capita	118	116	117	117	116	112	110	107
KGOE/Capita	45	44	44	44	44	43	42	41
KGOE/GDP(1972 price) (KGOE/1,000B)	6.6	6.2	5.9	5.8	5.6	5.6	5.0	4.4

Source: Thailand Energy Situation, NEA

3) Others

In addition to charcoal and firewood, other non-commercial energy such as rice husks and commercial energy such as LPG and electricity are used in this sector.

(a) Rice Husks

In 1988, 266 KTOE, or about 780 thousand tons of rice husks were consumed in this sector.

(b) LPG

The demand for LPG in Thailand is supposedly determined by the price of LPG vis-a-vis the prices of charcoal and firewood, the levels of disposable incomes of consumers, and the extent of coverage of the distribution system of LPG. LPG has been used in quantity as fuel in the residential and commercial sector since 1976. Since then the demand for LPG has been increasing as its superiority as cooking fuel became widely recognized, and the distribution system was established and containers and related equipment were made available. In the urban areas in particular, the introduction of LPG has been notable, which has contributed greatly to improvement of the living standards as well as cooking conditions. Use of LPG also contributes to the protection of forests which are being destroyed by the cutting down of trees for the production of charcoal and firewood. LPG also helps relieve Thai women of some of the burden of household chores. As Table 5-6 shows, the consumption of LPG in the residential and commercial sector was 199 KTOE in 1982, representing only 3.6 percent of the total energy consumption in this sector. In 1988, however, the consumption was 801 KTOE which accounted for 11.6 percent of the total in this sector or 3.0 per-

cent of the total energy consumption. Especially in Bangkok, between 60 and 70 percent of the households are considered to be using LPG for cooking. This tendency has been spreading to the provincial towns and rural farming areas.

Table 5-6 Historical Consumption of LPG

(Unit: Million Liters)

	1982	1983	1984	1985	1986	1987	1988	1989
Total	601	831	962	1,140	1,201	1,282	1,427	1,601
Residential	316	365	368	582	720	859	1,091	1,271
KTOE	199	230	232	367	454	541	687	801
Kl/Capita	7	7	7	11	14	16	20	23
KGOE/Capita	4	5	5	7	9	10	13	15
KGOE/GDP(1972) (KGOE/1,000B)	0.6	0.6	0.6	0.9	1.1	1.2	1.3	1.4

Source: Thailand Energy Situation, NEA

(c) Electricity

The consumption of electricity in the residential and commercial sector increased from 2,738GWh in 1982 to 7,025GWh in 1989. Electricity is used as energy source for electric appliances such as lights, air-conditioners, television sets, refrigerators, etc. in this sector. For cooking, electricity is used mainly for electric rice cookers, but the amount of consumption for this purpose is not available.

(3) Consumption of Firewood in the Manufacturing Sector

This section discusses the consumption of firewood in the manufacturing sector. Firewood has been an important source of energy for the industries in the northern and southern forest areas. In a case where the quality of fuel is not important, firewood is most probably chosen in preference to commercial energy because of its lower prices. Table 5-7 shows the consumption of firewood in the manufacturing sector. Charcoal is used by small-scale blacksmiths or bronze smelters in the country for heating metals; their consumption is apparently very small.

In the manufacturing sector firewood is consumed mainly by such industries as food processing industries including noodle making fac-

tories, rice mills, bakeries, sugar refineries, sauce factories, flour mills, and tobacco curing factories, saw mills, non-metal industries like brickyards, ceramic and glass factories.

Table 5-7 Historical Consumption of Firewood in Manufacturing Sector

	1982	1983	1984	1985	1986	1987	1988	1989
KTon	1,339	1,456	1,584	1,536	1,510	1,493	1,474	1,473
KTOE	507	551	600	581	572	527	558	557
Kg/Capita	28	29	31	30	29	28	27	27
KGOE/Capita	10	11	12	11	11	10	10	10
KGOE/GDP(1972) (KGOE/1,000B)	1.5	1.6	1.6	1.5	1.4	1.2	1.1	1.0

Source: Thailand Energy Situation, NEA

Estimates of firewood consumption in the manufacturing sector is summarized in Table 5-8.

Table 5-8 Estimated Firewood Consumption in Manufacturing Sector
(Unit: KTOE)

	1982	1983	1984	1985	1986	1987	1988
Food	n.a.	n.a.	n.a.	n.a.	n.a.	278	309
Wood	n.a.	n.a.	n.a.	n.a.	n.a.	32	32
Non-Metallic	n.a.	n.a.	n.a.	n.a.	n.a.	66	69
Basic Metal	n.a.	n.a.	n.a.	n.a.	n.a.	151	148
Total	507	551	600	581	572	527	558

Source: Mission's Estimation

5-1-3 Demand Forecast of Charcoal and Firewood

(1) Forecast of Energy Demand in the Residential and Commercial Sector

1) Indicators for Forecasting

Table 5-9 summarizes the estimates of forecast economic indicators which are used for forecasting the demand by the causal method.

These figures are developed based on discussions with, and the information provided by, the National Economic and Social Development Board of Thailand, NESDB for short, and the Bank of Thailand. Regarding the

possible influence on the economy of oil price increases caused by the Gulf crisis, which occurred in August 1990, it is assumed that the effect of the crisis will be phased out in the long run, although it will temporarily decrease the economic growth rate by approximately one percent.

Table 5-9 Forecast Economic Indicators

Actual			Average Growth Rate(%)	Forecast				Growth Rate 1989/ 2000
1975	1982	1989	1982-89	1995	2000	2005	2010	
GDP (Billion Bahts, Current Price Base)								
297.2	820.0	1,790.5	11.8	4,204.4	7,516.0	12,237.3	19,458.7	13.9
GDP Deflator (1.00 as of 1970)								
1.46	2.47	3.11	3.3	4.31	5.49	6.68	8.13	5.3
GDP (Billion Bahts, 1972 Price)								
204.1	331.4	574.9	8.2	974.9	1,368.3	1,831.1	2,393.1	8.2
Population (Million)								
41.9	48.7	55.2	1.8	59.9	63.4	66.7	70.1	1.3
GDP Per Capita (1,000 Bahts, Current Price)								
7.1	16.8	32.4	9.8	70.2	118.5	183.5	277.6	12.5
(US$,Current Price)								
348	731	1,296	8.5	2,808	4,740	7,340	11,104	12.5
GDP Per Capita (Bahts, 1972 Price)								
4,874	6,798	10,415	6.2	16,283	21,599	27,475	34,165	6.9
Exchange Rate (Bahts/US$)								
20.4	23.0	25.0	-	25.0	25.0	25.0	25.0	-

2) Result of Energy Demand Forecast in the Residential and Commercial Sector

Energy consumption in the residential and commercial sector increased from 5,502 KTOE in 1982 to 6,889 KTOE in 1989 at an average rate of 3.3 percent per year. In 1989 energy consumption in this sector accounted for 25.7 percent of the final energy consumption for the whole kingdom. It is forecast that the energy demand in this sector will reach 9,649 KTOE by 2000; this represents an increase of 3.1 percent per year from 1989 against the forecast rate of increase of 7.2 percent for the final energy consumption. As a result, its share in the final energy demand

will decrease to 16.7 percent. The rate of increase in this sector will be smaller compared to that in the transportation or manufacturing sector. The energy demand in this sector is forecast to be 12,627 KTOE with its share decreasing to 13.6 percent of the final energy demand by 2010.

The results of the forecast are summarized in Table 5-10. The final energy demand in the table was forecast by means of the equation developed by regression and multi-regression analyses using economic indicators. The results of the forecast were examined for correctness in terms of determination coefficient, growth rate of demand and per-capita consumption. After a repetition of such calculations, the most appropriate equation to be used for forecasting was selected and used. A similar procedure was employed to forecast the demand for energy in the residential and commercial sector. In addition, changes of the share of this sector in the final energy consumption were used to examine the correctness of the equation.

Table 5-10 Forecast Energy Demand of Residential & Commercial Sector

	Actual		Average Growth	Forecast				Growth Rate(%)
	1982	1989	Rate(%)	1995	2000	2005	2010	1989/2000
Final Energy Consumption								
KTOE	16,221	26,775	7.4	42,824	57,770	74,142	92,867	7.2
Final Energy Consumption per Capita								
KGOE	333	485	5.5	715	911	1,112	1,325	5.9
Energy Consumption of Residential & Commercial Sector								
KTOE	5,502	6,889	3.3	8,368	9,649	11,035	12,627	3.1
Energy Consumption of Residential & Commercial Sector per Capita								
KGOE	113	125	1.5	140	152	165	180	1.8
Energy Consumption of R & C Sector vs. Final Energy Consumption								
%	33.9	25.7	-	19.5	16.7	14.9	13.6	-

(2) Demand Forecast of Energy for Cooking Use

Energy consumption for cooking in the residential and commercial sector increased from 4,684 KTOE in 1982 to 5,316 KTOE in 1989 at an average rate of 1.8 percent per year. The consumption of energy for cooking accounted for 77.2 percent of the total consumption in this

sector in 1989, or about 96KGOE per capita.

The demand for energy in the residential and commercial sector is forecast to reach 6,025 KTOE in 2000 and 6,474 KTOE in 2010; however, the average annual growth rate from 1989 to 2000 will be low at 1.1 percent. This is because the population growth is expected to slow down, the habit of eating out will become more common, and more efficient fuels and stoves will be more commonly accepted, as GDP per capita increases. These factors will combine to decrease the per-capita demand for energy for cooking. The per-capita demand for cooking energy, 96KGOE in 1989, will decrease to 95KGOE by 2000 and further decrease to 92KGOE by 2010.

The consumption of energy for purposes other than cooking, for lights and electric appliances for example, is rapidly increasing. As a result, the share of the energy for cooking in the total energy consumption in this sector is decreasing. The share is forecast to decrease to 62.4 percent by 2000 and 51.3 percent by 2010.
The results of the demand forecast of energy for cooking are summarized in Table 5-11.

Table 5-11 Demand Forecast of Energy for Cooking

	Actual		Average Growth	Forecast				Growth Rate(%)
	1982	1989	Rate(%)	1995	2000	2005	2010	1989/2000
Energy Consumption of Residential & Commercial Sector								
KTOE	5,502	6,889	3.3	8,368	9,649	11,035	12,627	3.1
Energy Demand for Cooking								
KTOE	4,684	5,316	1.8	5,743	6,025	6,261	6,474	1.1
Energy Demand for Cooking per Capita								
KGOE	96	96	-	96	95	94	92	-
Energy Demand for Cooking vs for Residential & Commercial Sector								
%	85.1	77.2	-	68.6	62.4	56.7	51.3	-

The demand for energy for cooking in the residential and commercial sector was forecast by the regression and multi-regression analyses using equations developed with economic indicators as inputs. The results obtained by such equations were examined for correctness of the equations in terms of determination coefficient, growth rate of

demand, and per-capita consumption. This operation was repeated until an appropriate equation to be used for forecasting was obtained.

(3) Demand Forecast of Charcoal and Firewood in the Residential and Commercial Sector

There are certain areas where the consumption of charcoal in this sector has increased through conversion from firewood; however, in other urban and suburban areas charcoal is being rapidly replaced by LPG.

The consumption of charcoal in this sector decreased from 2,227 KTOE in 1982 to 2,008 KTOE in 1989 at an average rate of minus 1.5 percent per year. In 1989, the consumption of charcoal accounted for 37.8 percent of the total energy consumed for cooking. The demand for charcoal is forecast to decrease to 1,699 KTOE by 2000 at an average rate of minus 1.5 percent per year for the period from 1989 to 2000 and its share in the total energy consumption for cooking is forecast to decrease to 28.2 percent. THe demand for charcoal is forecast to further decrease after 2000 as substitution by LPG and other fuels proceeds.

Firewood consumption for cooking in the sector increased from 2,169 KTOE in 1982 to 2,241 KTOE in 1989 at an average rate of 0.5 percent per year. However, the total consumption of firewood has been decreasing since it peaked at 2,313 KTOE in 1986. The consumption of firewood for cooking in 1989 accounted for 42.2 percent of the total energy consumption for cooking in the sector. The demand for firewood for cooking is forecast to be 2,037 KTOE in 2000 which will represent 33.7 percent of total energy consumption for cooking. The rate of growth of the demand is forecast to be minus 0.8 percent for the period from 1989 to 2000 because firewood will be partly replaced by LPG and charcoal.

Table 5-12 shows the forecast demand of energy for cooking with breakdowns into charcoal, firewood and other fuels.

The demand for charcoal in the sector was forecast by means of regression analysis using GDP, population, calendar year, energy consumption for cooking as the variables.

Table 5-12 Forecast Demand of Energy for Cooking by Type

(Unit: KTOE)

	Actual		Average Growth	Forecast				Growth Rate(%)
	1982	1989	Rate(%)	1995	2000	2005	2010	1989/2000
Energy Demand for Cooking	4,684	5,316	1.8	5,743	6,025	6,261	6,474	1.1
Breakdowns								
Charcoal	2,227	2,008	-1.5	1,822	1,699	1,596	1,503	-1.5
Firewood	2,169	2,241	0.5	2,118	2,037	1,968	1,907	-0.8
Paddy Husks	99	266	17.1	250	250	250	250	-
LPG, etc.	189	801	22.9	1,553	2,039	2,447	2,814	8.9

The demand for firewood in the sector is forecast in a similar manner by means of regression analysis using GDP, population, calendar year, energy consumption for cooking as variables.

The sum of the demands for charcoal and firewood was forecast by regression analysis with the total cooking energy as the variable; the forecast sum was used to examine the forecast charcoal demand and the forecast firewood demand.

The demand for rice husks was forecast not to grow but to remain at the present level because of their inferior quality as cooking fuel as expressed by the consumers who were interviewed.

The demand for LPG in this sector was obtained by subtracting the sum of forecast demands for charcoal, firewood, and rice husks from the total forecast demand for cooking energy in this sector and then reconciling the results with the demands forecast by Petroleum Authority of Thailand, PTT.

The equations and coefficients used for regression analysis are shown at the end of this section.

(4) Demand Forecast of Energy in the Manufacturing Sector

1) Demand Forecast of Energy in the Manufacturing Sector

The forecast demand of energy in the manufacturing sector is sum-

marized in Table 5-13.

Table 5-13 Forecast Demand of Energy in Manufacturing Sector

	Actual		Average Growth	Forecast				Growth Rate(%)
	1982	1989	Rate(%)	1995	2000	2005	2010	1989/2000
Final Energy Consumption								
KTOE	16,221	26,775	7.4	42,824	57,770	74,142	92,867	7.2
Final Energy Consumption per Capita								
KGOE	333	485	5.5	715	911	1,112	1,325	5.9
Energy Consumption by Manufacturing Sector								
KTOE	4,728	7,712	7.2	11,947	16,572	22,012	28,618	7.2
Energy Consumption by Manufacturing Sector per Capita								
KGOE	97	140	5.4	199	261	330	408	5.8
Energy Consumption by Manufacturing Sector vs. Final Energy Consumption								
%	29	29	-	28	29	30	31	

The demand for energy in the manufacturing sector is forecast based on an equation developed by means of the regression analysis and multi-regression analysis with the economic indicators as variables. The results of the forecast were examined in the light of the coefficients, growth rates and per-capita consumption. This operation was repeated until the most appropriate equation was identified. The final forecast was obtained by using the selected equation.

2) Demand Forecast of Firewood in the Manufacturing Sector

Charcoal is consumed in some small-scale rural metal industries such as blacksmiths or bronze-smelters, but the amount they use may be considered to be very small. The food-processing industries, saw-mills, metal and non-metal industries together consumed firewood equivalent to 507 KTOE in 1982 and 557 KTOE in 1989. Their consumption has been decreasing since registering a peak consumption of 600 KTOE in 1984 because of the supply becoming tight and the resultant price increases. Lignite and LPG are replacing firewood. Table 5-14 summarizes the consumption of firewood in the manufacturing sector.

Table 5-14 Forecast Demand of Firewood in Manufacturing Sector

	Actual		Average Growth	Forecast				Growth Rate(%)
	1982	1989	Rate(%)	1995	2000	2005	2010	1989/2000
Energy Demand in Manufacturing Sector								
KTOE	4,728	7,712	7.2	11,947	16,572	22,012	28,618	7.2
Firewood Demand in Manufacturing Sector								
	507	557	1.4	472	402	319	218	-3.0

(5) Demand Forecast of Charcoal and Firewood

Table 5-15 summarizes the forecast demands for charcoal and firewood.

Charcoal is used as a cooking fuel in the residential and commercial sector, while firewood is consumed in certain manufacturing industries in addition to cooking use. Therefore, the forecast demand for charcoal is based on the forecast demand for charcoal and firewood in the residential and commercial sector in Section 5-4-3, while the forecast demand for firewood is the sum of the forecast demand for firewood in the residential and commercial sector and that in the manufacturing sector, as discussed in Sections 5-1-3(3) and 5-1-3(4), respectively.

Table 5-15 Demand Forecast of Charcoal and Firewood

	Actual		Average Growth	Forecast				Growth Rate(%)
	1982	1989	Rate(%)	1995	2000	2005	2010	1989/2000
Demand for Charcoal (KTOE)								
Cooking	2,227	2,008	-1.5	1,822	1,699	1,596	1,503	-1.5
Demand for Firewood (KTOE)								
Cooking	2,169	2,241	0.5	2,118	2,037	1,968	1,907	-0.8
Manu-facturing	507	557	1.4	472	402	319	218	-3.0
Total	2,676	2,798	0.6	2,590	2,439	2,287	2,125	-1.3
Grand Total	4,903	4,806	-0.3	4,412	4,138	3,883	3,628	-2.5

5-1-4 Charcoal and Firewood Consumption by Region

(1) Estimates of Charcoal and Firewood Consumption by Region

1) Regional Characteristics

Table 5-16 summarizes the consumption of energy by region.

Table 5-16 Average Monthly Fuel Consumed per Household by Region (1986) (Unit: Liter)

	Whole Kingdom Area	Bangkok M'politan	Central Region	Northern Region	North Eastern Region	Southern Region
Av.Household Size	4.3	3.8	4.2	3.9	4.9	4.2
Petroleum Products						
Regular Gasoline	5.08	5.10	7.30	4.86	3.04	7.40
Premium Gasoline	1.09	10.54	0.82	1.11	0.17	1.17
High Speed Diesel	1.14	1.24	1.86	1.54	0.77	0.22
Low Speed Diesel	0.06	0.02	0.01	0.12	0.08	0.01
Kerosene	0.70	0.09	0.66	0.68	0.84	1.02
Lub Oil	0.20	0.18	0.25	0.24	0.14	0.23
LPG-Cooking(Kg)	1.44	4.40	2.50	0.70	0.26	1.43
LPG-Vehicles(Kg)	0.12	0.37	0.34	0.06	-	-
LPG-Others(kg)	0.01	0.01	0.01	0.00	0.00	0.00
Other Products						
Charcoal(Kg)	21.54	6.33	18.42	24.67	29.37	14.78
Wood(Kg)	30.56	6.87	16.68	28.05	50.52	26.52
Electricity(KWh)	42.32	112.70	52.84	31.38	20.01	37.44

Source: NSO Energy Consumption Survey 1986

In Bangkok and its suburbs, LPG is consumed in large amounts, supported by the well-established distribution system of LPG, whereas the consumption of charcoal and firewood is small. In Central Region where forests are scarce, wood fuel has to be supplied from other regions and, consequently, the consumption of LPG is relatively large. On the contrary, Northern, Northeastern, and Southern Regions consume charcoal and firewood in large amounts, since wood fuel is relatively easy to secure there.

2) Community Characteristics

The pattern of energy consumption for the household use may be characterized not only by region but also by type of community. The municipal areas tend to consume more commercial energy, petroleum

products for example, while the rural areas consume more non-commercial energy such as charcoal and firewood. Table 5-17 shows the patterns of fuel consumption by community.

Table 5-17 Average monthly Fuel Consumed per Household by Community (1986)

(Unit: Liter)

	Whole Kingdom	Municipal Area	Sanitary District	Villages
Av.Household Size	4.3	3.8	4.1	4.5
Petroleum Products				
Regular Gasoline	5.08	11.00	7.26	4.14
Premium Gasoline	1.90	2.94	0.85	0.43
High Speed Diesel	1.14	2.64	1.91	0.86
Low Speed Diesel	0.06	0.13	-	0.07
Kerosene	0.70	0.15	0.30	0.92
Lub Oil	0.20	0.43	0.27	0.17
LPG-Cooking(Kg)	1.44	3.51	1.93	0.64
LPG-Vehicles(Kg)	0.12	0.20	0.12	0.07
LPG-Others(kg)	0.01	0.02	-	0.00
Other Products				
Charcoal(Kg)	21.54	17.05	21.66	24.63
Wood(Kg)	30.56	8.48	20.61	38.27
Electricity(KWh)	42.32	88.87	52.29	23.98

Source: NSO Energy Consumption Survey 1986

The lifestyle, cooking habits and stoves are explained briefly for the municipal and rural areas below.

(a) Municipal Area

The large cities as represented by Bangkok and small cities in the provinces are markedly different in lifestyles. Especially in the central part of Bangkok, there are many high-rise buildings and neat shops lining the streets which are crowded with cars and people. However, in the outskirts of Bangkok and provincial cities the buildings are low, the shops are of traditional style and few houses are of modern style, but are mostly wooden and roofed with galvanized plate. People live in the more traditional lifestyles with the less western influence the further away they live from Bangkok.

The well-off households in Bangkok cook their food with LPG and their rice with electric cookers. There is a tendency that the further one

goes into the country, or to the lower-income households even in the urban areas, one sees the more charcoal used in addition to, or instead of LPG. Firewood is seldom used in the urban areas. Table 5-18 shows the historical energy use in the urban areas by percentage.

Table 5-18 Energy Used in Household Cooking by Areas

(Unit: %)

	Bangkok									
	Char	Wood	LPG	Others	Non	Char	Wood	Gas	Elec	Others
1962						91.0	-	-	-	9.0
1970						83.0	2.0	11.0	-	4.0
1976	56.5	9.1	12.3	20.9	1.2					
1980						43.0	4.0	44.0	6.0	3.0
1981	38.1	12.9	24.9	14.0	10.1					
1986	18.7	12.7	40.5	11.8	16.3					
	Municipal					Provincial				
	Char	Wood	LPG	Others	Non	Char	Wood	Gas	Elec	Others
1962						77.0	22.0	-	-	3.0
1970						79.0	13.0	6.0	-	2.0
1976	60.9	8.4	9.0	19.6	2.1					
1980						59.0	14.0	19.0	6.0	2.0
1981	47.3	12.2	20.7	14.2	5.6					
1986	30.7	10.5	35.2	11.8	11.8					

Source: NSO, Socioeconomic Survey NESDB, Rural Energy in Thailand

(b) Rural Farming Area

The infrastructure is not well-established in most rural areas. The income levels and savings are generally lower compared to the urban area. People seldom buy commercial fuels except when they are needed for agriculture or transportation. In remote rural areas people tend to collect wood for their own consumption within their village or in nearby forests. They also produce charcoal for their own consumption and sell whatever the surplus they have.

Table 5-19 summarizes the historical consumption of energy for cooking by area.

Table 5-19 Rural Energy Used in Household Cooking by Areas

(Unit: %)

	Char	Wood	LPG	Others	Non	Char	Wood	Gas	Elec	Others
1962						32.0	67.0	-	-	1.0
1970						38.0	60.0	1.0	-	1.0
1976	38.4	49.0	0.3	12.2	0.1					
1980						54.0	41.0	3.0	1.0	1.0
1981	41.1	53.6	1.7	2.9	0.7					
1986	47.4	43.3	5.5	2.7	1.1					

Source: NSO, Socioeconomic Survey NESDB, Rural Energy in Thailand

(2) Forecast of Demand for Charcoal and Firewood by Region

Table 5-20 shows the forecast demand for charcoal and firewood by region derived from statistics on population and energy consumption by region and community.

Table 5-20 Wood Fuel Demand by Areas

(Unit: KTOE)

	1989	1995	2000	2005	2010
Charcoal					
Bangkok Metropolitan	50	45	41	38	35
Central	391	355	331	311	293
North	512	465	435	409	386
Northeast	879	798	744	699	658
South	175	159	148	139	131
Whole Kingdom	2,008	1,822	1,699	1,596	1,503
	1989	1995	2000	2005	2010
Firewood					
Bangkok Metropolitan	34	29	26	22	18
Central	352	326	307	288	267
North	598	556	525	494	462
Northeast	1,502	1,391	1,310	1,228	1,141
South	312	289	272	255	237
Whole Kingdom	2,798	2,590	2,439	2,287	2,125

5-1-5 Supply of Charcoal and Firewood

Forest areas are decreasing at an alarming rate in Thailand. They decreased from 270,000km^2, or 53 percent of the country, in 1961 to 140,000km^2, or 28 percent of the total area of the country, by 1988. In other words, Thailand lost an average of 4,800km^2 per year of forest area during the period. If the deforestation continues at this pace, forests in Thailand will have disappeared in thirty years. Under these circumstances, the government of Thailand is promoting reforestation and regulates cutting down of trees, aiming to recover the forest area to 40 percent of the country. However, these efforts have not met with great success in the face of the very pressing need for wood. Nevertheless, the supply of charcoal and firewood will sharply decrease because of the effects of government policy and the anticipated shortage of forest resources.

Regarding the limitation on the supply of wood fuel to be imposed by the scarce forest resources, the following three hypothetical scenarios were assumed. The supply of wood fuel was calculated for these scenarios as shown in Tables 5-21 to 5-23.

Case 1: The volume of trees cut down will decrease at 6 percent per year as a result of government regulations. These trees are consumed preferentially as firewood to meet the demand for firewood. The rest is used for charcoal manufacturing.

Case 2: The volume of trees cut down is the same as in Case 1; however, 30 percent of this volume will be consumed as firewood and 70 percent for charcoal.

Case 3: No restrictions will be imposed on the cutting down of trees. The volume of trees necessary for meeting the demands for charcoal and firewood will be made available.

The following three assumptions were made for calculating the supplies of charcoal and firewood.

(1) Forest Resources

According to the Food and Agricultural Organization, FAO, the forest resources was 667 million cubic meters in 1978. Assuming that the forest density, or tree volume per unit area, has remained uniform and constant throughout the nation, forest resources are estimated at 587.3 million cubic meters based on the size of the forest area in 1983.

(2) Sustainable Wood Supply

"Energy Sector Management Assistance Program" prepared jointly by the United Nations and the World Bank estimated the sustainable wood supply in 1983 to be 15.5 million cubic meters. By comparing this number with the above-stated forest resources in 1983, the sustainable wood supply is estimated to be 2.64 percent of the total volume of the forest resources.

(3) Reforestation

The total area reforested by the public and private sectors up to 1988 was 6,690 km^2. In the past, more than 70 percent of such reforestation efforts aimed to recover lost forests and the rest was for commercial planting to obtain wood for paper production. It is assumed, based on past records, that in the future 400km^2 of land will be planted annually and that the wood from 30 percent of such reforested areas will be used for the production of charcoal and firewood. It is also assumed that trees planted for the purpose of obtaining wood fuel will be cut down in five-year cycles, and each rai, or 1,600 m^2, of land will produce 4 tons, or 5m^3, of wood every five years.

In Case 3, as is evident from the table, the natural forests will almost disappear by 2010. It is hardly conceivable that this situation will actually be allowed to happen. The forecasts in this case underscore the importance of controlling the cutting down of trees.

In Case 2, the total supplies of wood fuel, including both charcoal and firewood, are the smallest among the three cases, though the supply of charcoal will be greater than in Case 1. It would be very difficult to

restrict the supplies of firewood at low levels indicated in this case, because firewood is produced mostly by consumers themselves, whether legally or illegally.

Table 5-21 Estimated Supply of Wood Fuel (Case-1)

	1989	1995	2000	2005	2010
Forest Area(km^2)					
Natural Forest	137,684	101,451	79,691	64,396	53,943
Planted Forest					
Protective Forest	280	1,960	3,360	4,760	6,160
Productive Forest	120	840	1,440	2,040	2,640
Total Forest Area	138,084	104,251	84,491	71,169	62,743
Forest Volume(million m^3)	524.0	386.1	303.3	245.0	205.3
Sustainable Supply Vol.(million m^3)					
Natural Forest	13.83	10.19	8.01	6.47	5.42
Planted Forest	--	0.38	0.75	1.13	1.50
Total	13.83	10.57	8.76	7.59	6.92
Supply Volume					
Total Supply(million m^3)	37.4	29.2	21.4	15.7	11.5
Total Supply(KTOE)	8,496	6,628	4,865	3,570	2,620
Firewood(KTOE)	2,798	2,590	2,439	2,287	2,125
Charcoal(KTOE)	2,008	1,454	873	462	178

Table 5-22 Estimated Supply of Wood Fuel (Case-2)

	1989	1995	2000	2005	2010
Forest Area(km^2)					
Natural Forest	137,684	101,451	79,691	64,396	53,943
Planted Forest					
Protective Forest	280	1,960	3,360	4,760	6,160
Productive Forest	120	840	1,440	2,040	2,640
Total Forest Area	138,084	104,251	84,491	71,169	62,743
Forest Volume(million m^3)	524.0	386.1	303.3	245.0	205.3
Sustainable Supply Vol.(million m^3)					
Natural Forest	13.83	10.19	8.01	6.47	5.42
Planted Forest	--	0.38	0.75	1.13	1.50
Total	13.83	10.57	8.76	7.59	6.92
Supply Volume					
Total Supply(million m^3)	37.4	29.2	21.4	15.7	11.5
Total Supply(KTOE)	8,496	6,628	4,865	3,570	2,620
Firewood(KTOE)	2,798	1,998	1,226	1,071	786
Charcoal(KTOE)	2,008	1,670	1,459	900	660

It follows then that Case 1 appears the most realistic of these three cases. This study therefore calculated the supply demand balance of wood fuel using Case 1 as the base case. One justification supporting Case 1 is that forest protection and energy saving favor this case, because more than 50 percent of the energy originally contained in the wood is lost when charcoal is produced.

Table 5-23 Estimated Supply of Wood Fuel (Case-3)

	1989	1995	2000	2005	2010
Forest Area(km^2)					
Natural Forest	137,684	100,851	69,484	36,519	1,598
Planted Forest					
Protective Forest	280	1,960	3,360	4,760	6,160
Productive Forest	120	840	1,440	2,040	2,640
Total Forest Area	138,084	103,651	74,284	43,319	10,398
Forest Volume(million m^3)	524.0	383.8	264.4	139.0	6.1
Sustainable Supply Vol.(million m^3)					
Natural Forest	13.83	10.13	6.98	3.67	0.16
Planted Forest	--	0.38	0.75	1.13	1.50
Total	13.83	10.51	7.73	4.79	1.66
Supply Volume					
Total Supply(million m^3)	37.4	33.7	31.5	29.6	27.8
Total Supply(KTOE)	8,496	7,651	7,158	7,720	6,300
Firewood(KTOE)	2,798	2,590	2,439	2,287	2,125
Charcoal(KTOE)	2,008	1,822	1,699	1,596	1,503

5-1-6 Supply Demand Balance of Charcoal and Firewood

Table 5-24 summarizes the supply demand balance of wood fuel.

Table 5-24 Supply Demand Balance of Wood Fuel

(Unit: KTOE)

		1995	2000	2005	2010
Supply	Charcoal	1,454	873	462	178
	Firewood	2,590	2,439	2,287	2,125
Demand	Charcoal	1,822	1,699	1,596	1,503
	Firewood	2,590	2,439	2,287	2,125
Balance	Charcoal	-368	-826	-1,134	-1,325
	Firewood	0	0	0	0

It is forecast that the supply of charcoal will fall short of demand by 368 KTOE in 1995 and 1,325 KTOE in 2010. To solve this shortage, it is necessary to supply a suitable substitute fuel for charcoal and firewood which could be used in the residential and commercial sector, in particular. The substitute fuel should preferably be produced from domestic raw materials, not require expensive facilities to manufacture, be able to be supplied on the existing distribution channels for charcoal and firewood, be competitive with charcoal and firewood in price, and be as easy as charcoal or firewood to use.

Electricity, LPG, and city gas are also possible substitutes for charcoal and firewood. In addition to them, lignite briquettes are also one candidate for the substitute fuel.

Expanding the supply of electricity requires a large investment. Demand for electricity is also expected to increase very rapidly in other sectors. Using electricity for cooking is not an appropriate option from the standpoint of thermal efficiency. In addition, electricity will be too expensive for many consumers.

Imports of LPG to meet the supply shortage will result in greater foreign currency outflows. If the fuel shortage were to be made up for exclusively by LPG it would be necessary to increase the import of LPG, which was 801 KTOE in 1989, to 4,139 KTOE, or 2,814 KTOE plus 1,325 KTOE, by 2010 at an average rate of 8.1 percent per year. The extension of the distribution system and the construction of a number of primary and secondary terminals would be necessary.

To provide city gas, construction of a huge supply network is necessary. This is a problem requiring future study.

The lignite briquettes of this project could be produced from domestic raw materials only -- lignite, limestone, and rice straws --, would be competitive in price with charcoal, could be distributed on the existing distribution channels of charcoal, and would be even more convenient than firewood.

The forecast shortage in the supply of wood fuel should be solved by using an optimum combination of various kinds of energy.

Equations for Forecasting

1 Final Energy Consumption

Y=2.7985X-2,745 R2: 0.99

Y: Final Energy Consumption

X: GDP/CAPITA

2 Energy Consumption in the Residential and Commercial Sector

Y=1.9129X+151.9101Z-2592 R2: 0.99

Y: Energy Consumption in Residential and Commercial Sector

X: GDP

Z: Population

3 Energy Consumption for Cooking Use

Y=108.7991Z-642 R2: 0.97 and Y=-1.0638X+146.0641Z-2127 R2: 0.98

Y: Energy Consumption for Cooking Use

X: GDP

Z: Population

4 Energy Consumption for Cooking by Type

Charcoal Y=-0.4357X+4347 R2: 0.79

Y: Charcoal

X: Energy Consumption for Cooking Use

Firewood Y=-0.2882X+3779 R2: 0.78

Y: Firewood

X: Energy Consumption for cooking Use

5 Energy Consumption in the Manufacturing Sector

Y=11.7543X+449 R2:0.91

Y: Energy Consumption in the Manufacturing Sector

X: GDP

6 Firewood Consumption in Manufacturing Sector

Y=-0.1795X+647 R2: 0.30

Y: Firewood Consumption in Manufacturing Sector

X: GDP

5-2 Prospective Markets for Lignite Briquettes

This section present a summary of the preparatory field survey conducted from November to December 1989. The monitoring survey described in the following section was conducted from July to October 1990 chiefly on the markets identified as prospective by the preparatory survey.

5-2-1 Basic Principle for the Survey

(1) Object of Substitution

Lignite briquettes could be used as a substitute fuel for charcoal, firewood, and lignite judging from the quality of lignite briquettes. Firewood is a traditional fuel in Thailand along with charcoal. Firewood is widely used as cooking and industrial fuel especially in rural areas. Charcoal is superior to firewood in quality in that charcoal does not produce smoke when it burns and that charcoal has a higher heating value and thus is suited to long-distance transportation. Charcoal is used mainly for cooking in a large number of households and restaurants either by itself or together with firewood and LPG. In the manufacturing sector, charcoal is used for metallurgy and the like but the consumption for such purposes is very small. Lignite is consumed in large volume for power generation and cement manufacturing. Lignite is consumed in such small- or medium-scale industries as tobacco curing factories, lime kilns and the like as substitute fuel for firewood.

One of the objectives of the preparatory field survey was to identify which of these fuels used in each application could be replaced by lignite briquettes from technical and economic viewpoints.

(2) Selection of Prospective Market Area

As stated in Chapter 3, Thailand is divided into Northern, Northeastern, Central, and Southern Regions. Each region has its unique natural and cultural background. There are also differences in the patterns of

fuel consumption. Representative cities were selected from each region and these cities and their suburbs were surveyed.

(3) Field Survey Method

Visits were paid to charcoal burners, fuel dealers, consumers of various fuels and common households. The information on prices and distribution channels was obtained from charcoal burners and dealers, and that on retail prices, methods and facilities for consumption, and amounts of consumption was obtained from the consumers. The observations and interviews were conducted by the study team as means for obtaining information.

5-2-2 Sample Market

(1) Selection of Sample Market

As representative cities, those cities where regional energy centers of NEA are situated were selected. What to see and whom to visit were determined with the cooperation of the regional energy centers for the following reasons:

(1) Comprehensive cooperation from the Thai side is indispensable to successfully and efficiently executing the survey within the limited time available.

(2) NEA, the counterpart agency to the JICA study team in the survey, has regional energy centers strategically deployed in major cities of each region.

(3) The activities of the regional energy centers include promotion of high-efficiency charcoal kilns and improved cooking stoves and planting of fast-growing trees such as eucalyptus.

(4) Through the above activities, these regional energy centers are well informed of the supply and demand trends of non-commercial energy such as charcoal and firewood in their

regions, and maintain close relationships with people there.

The regional energy centers which assisted the survey are as follows:

(1) Northern Region: Chiang Mai, Phitsanulok
(2) Northeastern Region: Mahasarakham, Nakhon Ratchasima (Meteorological Observatory)
(3) Southern Region: Nakhon Si Thammarat

The representative city of Central Region is Bangkok. While working in Mahasarakham, Khon Kaen, a province adjacent to Mahasarakham, was also surveyed.

(2) Characteristics of Representative Markets

1) Chiang Mai

Chiang Mai is the largest and representative city of northern Thailand. Northern Region is rich in forest resources compared to other regions. The forest area constitutes about 50 percent of the region and supplies Central Region with charcoal. In addition, this region is a major producing area of lignite which is used for curing tobacco leaves, which are intensively cultivated in the area.

2) Phitsanulok

Phitsanulok is officially part of Northern Region. However, Phitsanulok is located on the edge of the Central Plain while Chiang Mai is in the mountainous area. Its major industry is agriculture. The area in which Phitsanulok is situated has characteristics similar to that of the Central Plain.

3) Mahasarakham/Khon Kaen

Khon Kaen is the second largest city in Northeastern Region and Mahasarakham is in a province adjacent to Khon Kaen. Northeastern Region is the site of one of the worst and most serious deforestation; and in some towns the shortage of fuel is serious.

4) Nakhon Ratchasima

Nakhon Ratchasima is the largest city in Northeastern Region and is located on the border with Central Region. The problem of fuel shortages is becoming serious here, too.

5) Nakhon Si Thammarat

Nakhon Si Thammarat is one of the representative cities of Southern Region. In Southern Region, rubber trees are intensively planted and old rubber trees are used as firewood and also burned to make charcoal. In addition, a great deal of charcoal is produced from mangroves, chiefly on the west coast of the Malay Peninsula. Charcoal produced from mangrove trees burns strong and for a long time. This area is one of the important supply sources of charcoal to Bangkok.

6) Bangkok

Demand for charcoal and firewood has been decreasing in Bangkok as the use of LPG is spreading rapidly. Nevertheless, a large amount of charcoal is supplied from Southern Region and consumed even after cutting down of trees was banned in January 1989.

(3) Result of Survey

A summary of major findings of the preparatory field survey is presented as follows.

1) Chiang Mai

Chiang Mai is adjacent to the mountainous areas where charcoal is produced in large amounts. Unlike Bangkok, large distributors of charcoal were not be identified. There are a couple of wholesalers who buy charcoal from producers and sell it to retailers or consumers. Producers also sell directly to consumers. The retail price of charcoal in Chiang Mai was high at 5 Bahts per kilogram though Chiang Mai is very near the producing areas.

2) Phitsanulok

The retail prices of charcoal in Phitsanulok were 5 Bahts per small bag of 1.2 kilograms, or 4.2 Bahts per kilogram, and 150 Bahts per large bag

of 38 kilograms, or 3.9 Bahts per kilogram. Prices in the suburban villages were from 110 to 130 Bahts per large bag of 38 kilograms, or from 2.9 to 3.4 Bahts per kilogram. The producer's price in the region was 70 Baths per 38 kilograms, or 1.8 Bahts per kilogram. Middlemen play an important role in the distribution and sale of charcoal in Phitsanulok.

3) Mahasarakham/Khon Kaen

Northeastern Region has very scarce forest resources except for planted eucalyptus. The charcoal producers in this region may be divided into two groups: large- and small-scale manufacturers. The former produce charcoal from eucalyptus using high-efficiency kilns, while the latter produce charcoal from various trees using primitive kilns. However, there is little difference between them in terms of the selling price. The retail prices in Mahasarakham and Khon Kaen were 5 Bahts per 1.5 kilograms or 3.3 Bahts per kilogram.

In Mahasarakham, a city smaller than Khon Kaen, the producers usually sell their charcoal directly to consumers. The roles of the middlemen or retailers are not important.

On the other hand, in Khon Kaen the middlemen play an important role in the distribution of charcoal. They collect charcoal produced by small-scale charcoal burners scattered in the suburbs.

4) Nakhon Ratchasima

Trees for charcoal production are difficult to secure in Nakhon Ratchasima. The retail price was 16 Bahts per 4.5 kilograms, or 3.6 Bahts per kilogram. Charcoal is usually sold by peddlers who visit their consumers early in the morning.

5) Nakhon Si Thammarat

Rubber trees are intensely planted in Southern Region. Old rubber trees are utilized as raw material for furniture and charcoal, and many people produce charcoal for their own consumption. There are large-scale manufacturers who supply charcoal to Bangkok.

6) Bangkok

In Bangkok, there are a number of large charcoal depots operated by wholesalers. Charcoal is transported from Southern Region by truck, and also, presumably, from the eastern and western mountainous areas. Either the producers or middlemen take charge of transportation. The wholesalers sell charcoal in large bag or divide it into small bags before selling to retailers and consumers. The wholesale price at the depots was 150 Bahts per 50 kilogram, or 3 Bahts per kilogram. The retail price in Bangkok was 5 Bahts per small bag of one kilogram.

5-2-3 Prospective Markets for the Lignite Briquettes

The conclusion drawn from the field survey are summarized as follows.

(1) Residential and Commercial Sector

It was concluded from the preparatory field survey that in Bangkok, Chiang Mai, Phitsanulok and their surroundings, lignite briquettes have a good prospect of being marketed at prices competitive with that of charcoal. Other cities surveyed may be regarded as having considerable potential demand for lignite briquette. However, it appeared inappropriate to attempt to draw a generalized conclusion on the prospect of markets from the survey conducted in such a limited time and in such limited areas. Therefore, a more comprehensive survey was conducted in the monitoring survey.

(2) Manufacturing Sector

The possibility of lignite briquettes being used as a substitute for firewood, charcoal or lignite burned in small- and medium-scale industries were studied. Large industries burning natural gas or petroleum products under precise control cannot be expected to use lignite briquettes. In order for lignite briquettes to be accepted by these small- and medium-scale industries, lignite briquettes must burn well without the need for significant modifications of their facilities. The survey team visited a tobacco curing factory, ceramic factories, brickyards, lime kilns, noodle-makers, and silkworm growers. It was

found necessary to conduct burning tests in these facilities.

5-3 Marketability of Lignite Briquettes

5-3-1 Basic Policy for Study on the Marketability of Lignite Briquette

The results of the preparatory field survey indicate that the potential market for lignite briquettes lies in substitution for charcoal in the residential and commercial sector. It was also considered possible that lignite briquettes could substitute for the conventional fuels used in small- and medium-sized industries, provided that the price is competitive and that the existing facilities could accommodate lignite briquettes without the need for significant modifications. The possibility of lignite briquettes being a substitute for firewood was denied later as a result of the monitoring survey, as is explained in 5-3-3 (2).

The potential of lignite briquettes as substitute for charcoal for cooking was confirmed by the monitoring survey. However, the possibility of substitution for conventional fuels used in industries was found almost none. The samples used for the monitoring survey were manufactured by the bench-scale plant installed at Rangsit in the suburbs of Bangkok from the domestic raw materials of Thailand. The monitoring survey was supported by regional energy centers of NEA for surveys in their respective territories.

5-3-2 Monitoring Survey

(1) Objectives of the Monitoring Survey

The monitoring survey was conducted from July to October 1990. The objectives of the monitoring survey are as follows.

(1) To finalize the quality standards of lignite briquettes meeting the consumers' requirements by observing the reactions of the potential consumers to the demonstrations and by analyzing replies to the questionnaires on the samples of lig-

nite briquettes, and to revise, if necessary, the tentative quality design set during the preparatory field survey.

(2) To assess the possibility of acceptance of lignite briquettes by the market as a substitute for cooking charcoal by an analysis of the responses from the selected potential consumers to the samples, in particular, to relate the degree of acceptance in the market with relative price between lignite briquettes and charcoal. To study also regional and social characteristics with respect to market acceptance.

(3) To observe industrial facilities that could burn lignite briquettes and study technical problems associated with using lignite briquettes and their solutions.To study also socio-economic implications with regard to the use of lignite briquettes by industries.

The samples of lignite briquettes used for demonstration were manufactured by the bench-scale plant installed at Rangsit near Bangkok from the Thai domestic raw materials. The same lignite briquettes were distributed among the selected potential consumers for opinion surveys.

(2) Achievements of the Monitoring Survey

The monitoring survey achieved the following objectives.

(1) The quality of lignite briquettes required by the market was made clear by analyzing the reactions of the potential consumers to the demonstrations and also to the samples provided to them. The results are discussed in Chapter 6.

(2) The possibility of lignite briquettes being accepted as a substitute for cooking charcoal was confirmed. The relationship between the degree of market acceptance and the ratio of price of lignite briquettes to that of charcoal was analyzed. The results obtained was used in the forecast of the demand for lignite briquettes.

(3) Various small and medium-sized industries considered as candidate for using lignite briquettes were inspected. Their technical problems associated with burning lignite briquettes, their solutions, and socio-economic implications were studied and clarified.

(3) Methods for the Monitoring Survey

For the monitoring surveys for the residential and commercial sector, demonstrations for burning lignite briquettes were conducted with the participation of the potential consumers. Specifically, lignite briquettes and charcoal were burned concurrently in the common Thai cooking stoves under the same conditions to steam rice. After the demonstrations, three to eight kilograms of samples of lignite briquettes were distributed among the participants together with the questionnaire shown in Table 5-25. The questionnaires were collected later via regional energy centers. Two rounds of monitoring surveys were conducted through the cities where regional energy centers are situated. Some of the respondents to the questionnaires were interviewed during the second round of the monitoring survey. The second round also supplemented information which had not been collected during the first round.

For the monitoring surveys for the industrial sector, samples of lignite briquettes were burned in the commercial facilities with the participation of the staff of the factories. Discussions were held after the burning tests.

(4) Areas for the Monitoring Survey

Thailand may be divided into Northern, Northeastern, Central and Southern Regions; each region has its own regional characteristics. The areas around the regional energy centers were covered in the survey to grasp the regional characteristics of the market. In addition, Bangkok was included in the survey, because a large amount of charcoal is considered to be used by certain groups of its large population and also by restaurants, although LPG is used mainly. The survey was con-

ducted in and around the following cities:

(1) Northern Region: Chiang Mai, Phitsanulok
(2) Northeastern Region: Mahasarakham/Khon Kaen, Ubon Ratchatani
(3) Central Region: Bangkok, Ratchaburi
(4) Southern Region: Nakhon Si Thammarat

(5) Subject of the Monitoring Survey

1) Charcoal

Charcoal is consumed mainly by the residential and commercial sector; therefore, the monitoring survey was focused upon general households, restaurants, and ready-made food vendors. In the industrial sector, small-scale metallurgical industries were surveyed for studying the possibility of substitution by lignite briquettes for charcoal.

2) Firewood

The firewood used in the residential and commercial sector is apparently very difficult for lignite briquettes to substitute for because of the very low prices of firewood. Therefore, the monitoring survey was not particularly concentrated on firewood. In the industrial sector, selected small- and medium-scale industries were surveyed to evaluate their possibility of burning lignite briquettes with associated needs for modifications of the facilities. A burning test was conducted in a pottery. Other installations were inspected by the study team and their technical problems in burning lignite briquettes were studied.

3) Lignite

Lignite is not used as household fuel; its industrial consumption was the only subject for substitution by lignite briquettes. A burning test was conducted in a tobacco curing barn. Some of the lime kilns burning lignite were studied for possibility of burning lignite briquettes. The advantages and disadvantages of using lignite briquettes were studied.

Table 5-25 Questionnaire of the Monitoring Survey

1. Background

(1) Name of Province: _____
(2) Community Type: (Urban/Sanitary/Village)
(3) Household Size: adults ___; Children (under 16) ____
(4) Major Food: _____
(5) Cooking Place: (Inside/Outside/Under Shelter)
(6) Major Cooking Fuel:_____; Other Cooking Fuel: _____, _____
(7) Price and Consumption Volume of Firewood and/or Charcoal
(only for users of firewood and/or charcoal)
(a) Firewood: ___ Bahts/kg: ___ kg/month
(b) Charcoal: ___ Bahts/kg: ___ kg/month
(8) Type of Food Usually Cooked
(a) Breakfast: (boiled/roasted/steamed/fried)
(b) Lunch: (boiled/roasted/steamed/fried)
(c) Dinner: (boiled/roasted/steamed/fried)
(9) Socio-economic Class: (farmer with land/farmer without land/
own business/employee/government official)
(10) Annual Income: Bahts/Household

2. Quality of the Lignite Briquettes

(1) Ease with which to Start Fire: (excellent/good/fair/poor)
(2) Smoke Generation: (tolerable/intolerable)
(3) Smell: (tolerable/intolerable)
(4) Heating Power: (excellent/good/fair/poor)
(5) Strength: (excellent/good/fair/poor)
(6) Appearance: (excellent/good/fair/poor)
(7) Overall evaluation: (excellent/good/fair/poor)

3. Substitute by Lignite Briquettes

If firewood and charcoal are no longer available in the near future, can lignite briquettes be used as cooking fuel? (yes/no)
If yes, write down what you think would be the reasonable price level of lignite briquettes. _____ Bahts/kg
If no, state the type of fuel which your households would like to use.

LPG	(yes/no)
Paddy Husks	(yes/no)
Electricity	(yes/no)
Kerosene	(yes/no)
Others	

(6) Schedule for the Monitoring Survey

The monitoring survey was conducted according to the schedule shown below. This schedule was set taking into account the production plan of lignite briquettes by the bench-scale plant.

First round: 40 days from July 10 to August 18
Second round: 29 days from September 2 to September 30
Survey in Bangkok: 5 days, October 3, 4, 7, 8 and 12

(7) Program of the Monitoring Survey

The schedule, the subject of the survey and the places of demonstrations are explained below.

1) First Round of the Monitoring Survey

(a) Nakhon Si Thammarat

A monitoring survey was done for three days from July 11 to July 13 focusing on households using charcoal. Demonstrations were conducted at the regional energy center, a school and a temple. A total of 35 samples were distributed.

(b) Ratchaburi

Two demonstrations were conducted on July 17, once in the morning and again in the afternoon both at a farming village. Samples were distributed to 60 people. On July 18, three lime kilns, one pottery and two stove factories were visited.

(c) Ubon Ratchatani

Four demonstrations were held during the five-day period from July 23 to July 27. The number of the samples distributed is 46. Blacksmiths and a bronze smelter of cottage-industry scale were visited and the lignite briquettes were burned as a test there.

(d) Mahasarakham

Three provinces, Mahasarakham, Khon Kaen and Roi Et, were surveyed

during the five-day period from July 30 to August 3. Four demonstrations, one each at the regional energy center of Mahasarakham, at two villages in the suburbs of Khon Kaen and at the Army Camp at Roi Et, were held for housewives. A total of 40 samples were distributed. A lecture and a demonstration were given at Srinakharinwirot University at Mahasarakham. A sausage factory and a noodle factory were visited.

(e) Phitsanulok

Six demonstrations were conducted during the five-day period from August 6 to August 10 mainly for housewives at nearby villages and the regional energy center. A total of 65 samples were distributed. A noodle factory and a tire regeneration factory were visited.

(f) Chiang Mai

Three demonstrations were done during the five-day period from August 13 to August 17. A total of 90 samples were distributed. A tobacco curing factory and a pottery were visited where a combustion test for the second round of survey was discussed.

2) Second Round of the Monitoring Survey

(a) Nakhon Si Thammarat

Nakhon Si Thammarat was surveyed for three days from September 3 to September 5. Demonstrations were done at a restaurant, a curry shop and a housewife group. Nine samples were distributed. A rubber drying factory was visited.

(b) Ratchaburi

Ratchaburi was surveyed from September 10 to 11. The two villages where demonstrations were done previously were visited for interviews. A lecture was given at a university. A paper mill burning lignite was visited.

(c) Ubon Ratchatani

The study team stayed here for three days from September 13 to 16. All the villages where demonstrations had been done previously were visited for interviews. A lecture was given at a university.

(d) Mahasarakham

Three days were spent in this area to cover Mahasarakham, Khon Kaen and Roi Et Provinces. Interviews were done at all the villages visited previously. Demonstrations were done at a housewife group in Mahasarakham and a restaurant. A total of 13 samples were distributed in this area.

(e) Phitsanulok

The recipients of the samples were interviewed on September 21, 22 and 24 at five villages previously visited. A demonstration was done at a restaurant. A lecture was given at two universities.

(f) Chiang Mai

Chiang Mai was surveyed for five days from September 26 to 29. Interviews were conducted at three places visited the previous time. A demonstration was done in the city of Chiang Mai, and a total of 34 samples were distributed. A lecture was also given at a university. Furthermore, a combustion test was conducted at a tobacco curing barn and a pottery.

3) Monitoring Survey in Bangkok

The survey in Bangkok was done in the beginning of October with five demonstrations including one at a restaurant and 106 samples distributed, after the second round of the monitoring survey.

5-3-3 Results and Evaluation of the Monitoring Survey

The outcomes of the monitoring survey are discussed below separately for the residential and commercial sector and the industrial sector.

(1) Residential and Commercial Sector

1) Rural Area

(a) Evaluation of the Performance

Table 5-26 gives the numbers of the questionnaires distributed, recov-

ered and interviews conducted.

Out of the 327 replies received, those indicating unwillingness for using lignite briquettes numbered only eight. In other words, about 98 percent of the respondents indicated some possibility of accepting lignite briquettes. The reasons cited for not accepting lignite briquettes are generation of smoke and odor. One reply indicates slow ignition. Many replies mention smoke and odor as a problem, but not to such an extent as to rejecting lignite briquettes for it.

Table 5-26 Summary of Monitoring Survey Activity

	Number of Questionnaires		Interviewed
	Delivered	Recovered	
Nakhon Si Thammarat	52	51	18
Ratchaburi	60	34	18
Ubon Ratchatani	46	46	32
Mahasarakham	53	40	26
Phitsanulok	66	64	30
Chiang Mai	124	92	27
Total	401	327	151

The item of quality most complained in the questionnaire is the generation of odor pointed out by 35 percent of the replies. However, it was confirmed through the interviews that many were worried about the odor of lignite briquettes, just because they were unfamiliar with the peculiar smell of burning coal. Therefore, the odor will not be a real deterrent to the acceptance of lignite briquettes in the market. About 30 percent of the replies pointed out generation of smoke. Again, the interviews revealed that smoke was generated only during the initial period of ignition, and posed no problem after lignite briquettes began to burn steadily. Therefore, the problem of smoke should be dealt with by improvement of stoves or even by starting fire at a place where there is a good ventilation, rather than modifications to the manufacturing process or to the formula of raw material blends, which could be an expensive option. This view was later modified; it was found that smoke could be a deterrent to dissemination of lignite briquettes among potential consumers and the modifications to the manufacturing process and the blending formula were finally made.

Some indicated that the larger sizes are more preferable. Through the interviews it became clear that most of them said so because they are accustomed to charcoal, the cakes of which are much larger than lignite briquettes. Some also said that the size of an egg is preferable; which certainly had a point in that the larger sizes would allow more air to be easily introduced into the stoves, perhaps resulting in suppression to some extent of smoke and odor during the initial period of combustion. However, there is a technical limitation on the manufacturing side to the size of the briquettes.

(b) Possibility of Substitution for Charcoal

Given that there is good possibility of lignite briquettes being accepted in the market, the extent of substitution of lignite briquettes for charcoal was studied with regard to the ratio of the price of lignite briquettes to that of charcoal as parameter. Table 5-27 shows the degree of acceptance developed from the recovered replies. The upper part of the table gives the rates of acceptance based on the all replies, while the lower part presents those developed from the interviewed replies only. Some of the respondents obviously mistook the meanings of the questions. Such mistakes are included uncorrected in the figures in the upper part; however, there is not a great difference between the upper and lower parts of the table. From either part of the table it may be said that 58 percent of the households surveyed expressed willingness to use lignite briquettes instead of charcoal if the price of lignite briquettes is 60 percent of that of charcoal, and 82 percent of the households if the price is 40 percent of that of charcoal. The degree of acceptance varies from one place to another, but not so much as to be statistically significant.

It is possible to forecast the magnitude of the market of lignite briquettes from the above table and the forecast shortage of supply of wood fuel developed in Chapter 5-1-6. However, different families use different amounts of charcoal. Therefore, the figures in the above table were converted into rates of substitution in terms of weight using the amount of charcoal consumed by each interviewed family as shown in Table 5-28, which indicates that 63 percent of the demand for charcoal may be substituted for by lignite briquettes if the price of

lignite briquettes is 60 percent of charcoal.

Table 5-27 Substitution Rate of Charcoal by Lignite Briquettes
(Unit: percentage of households)

LB Price/CC Price, percent	80	60	40	20	0
From recovered questionnaire					
Nakhon Si Thammarat	10.4	56.3	97.9	100.0	100.0
Ratchaburi	39.4	63.6	90.9	97.0	97.0
Ubon Ratchatani	33.3	51.1	71.1	82.2	97.8
Mahasarakham	38.9	63.9	77.8	97.2	97.2
Phitsanulok	16.9	46.2	69.2	84.6	93.8
Chiang Mai	47.9	69.0	87.3	97.2	98.6
Average	30.9	58.1	81.9	92.6	97.3
From interview					
Nakhon Si Thammarat	5.6	61.1	100.0	100.0	100.0
Ratchaburi	22.2	55.6	83.3	94.4	94.4
Ubon Ratchatani	40.6	59.4	81.3	90.6	96.9
Mahasarakham	42.3	73.1	76.9	96.2	96.2
Phitsanulok	10.0	50.0	76.7	90.0	100.0
Chiang Mai	37.0	51.9	81.5	96.3	96.3
Average	27.8	58.3	82.1	94.0	97.4

Table 5-28 Substitution Rate of Charcoal by Lignite Briquettes
(Unit: percentage by weight)

LB Price/CC Price, percent	80	60	40	20	0
Nakhon Si Thammarat	0.2	56.6	100.0	100.0	100.0
Ratchaburi	24.2	60.4	90.0	92.8	92.8
Ubon Ratchatani	35.3	55.9	75.9	86.7	94.4
Mahasarakham	37.4	86.1	88.0	99.5	99.5
Phitsanulok	7.3	51.9	80.5	91.4	100.0
Chiang Mai	51.9	65.7	81.7	89.8	89.8
Average	25.5	62.7	84.1	92.8	96.9

(c) Evaluation of Cooking Stove

The common Thai cooking stoves are made of porcelain, with three-layered structure. They are reinforced by steel plate on the outside. Stoves of this type, in various sizes and shapes, are used throughout the kingdom. One of the objectives of this feasibility study is to develop a design of cooking stove suited for burning lignite briquettes. Some Thai cooking stoves were brought to Japan during the preparatory field survey in order to test them to see whether they are suited for burning lignite briquettes. During the monitoring survey,

the common Thai cooking stoves are evaluated.

When introducing a new fuel like lignite briquettes in the market and trying to spread it among the common people, it would be best and encounter least resistance if it can be done without forcing people to change their lifestyles or cooking habits. When designing a new cooking stove, a due consideration must be given not only to the performance of the stove but also, or even more, to such aspects as price, availability of raw materials, ease of use and ease of production.

The burning tests in Japan as well as the monitoring survey in Thailand confirmed that the common Thai cooking stoves are suited for burning lignite briquettes. In other words, the Thai cooking stoves can burn lignite briquettes without any modifications. This fact means a great deal in the promotion of lignite briquettes among people. An experiment on a very common Thai cooking stove showed a thermal efficiency of 35 percent, which is very high for stoves of this type.

To say that the common Thai cooking stoves are good enough for burning lignite briquettes does not mean that they leave nothing to be desired. They would be better if they are modified to have secondary air inlets and provisions for the control of the primary air. A study on the modification of the Thai stoves was done in Japan and an improved version of stove was brought to NEA. Reference should be made to Chapter 19 for the study of the improvement of the design of cooking stoves.

2) Bangkok

At demonstrations held in Bangkok, 106 questionnaires were issued and 47 of them were recovered. Of the 47 replies 44 said that lignite briquettes could be used as a substitute for charcoal. Table 5-29 compares the outcomes of the monitoring survey with those obtained in other regions. It may be noted from this table that there is no significant difference between Bangkok and local cities.

Table 5-29 Substitution Rate of Charcoal by Lignite Briquettes
(Unit: percentage of households)

LB Price/CC Price, percent	80	60	40	20	0
From recovered questionnaire					
Nakhon Si Thammarat	10.4	56.3	97.9	100.0	100.0
Ratchaburi	39.4	63.6	90.9	97.0	97.0
Ubon Ratchatani	33.3	51.1	71.1	82.2	97.8
Mahasarakham	38.9	63.9	77.8	97.2	97.2
Phitsanulok	16.9	46.2	69.2	84.6	93.8
Chiang Mai	47.9	69.0	87.3	97.2	98.6
Average	30.9	58.1	81.9	92.6	97.3
Bangkok	35.1	56.8	70.3	83.8	91.9

3) Overall Evaluation

The results of the monitoring survey have established that lignite briquettes of the quality used for the survey will be basically acceptable to the market. There is no doubt that lignite briquettes have certain drawbacks compared with charcoal; however, these drawbacks may be compensated for by providing the lignite briquettes at a price lower than the price of charcoal.

However, there is a limit to the use of lignite briquettes stemming from the very nature of lignite. A large variety of organic compounds must be generated as a result of the incomplete combustion of lignite. Given that the effects of these substances upon the health were not known, use of lignite briquettes in a manner to directly grill food is not desirable, particularly during the period when lignite briquettes are generating smoke.

Generation of smoke also puts some restriction on the use of lignite briquettes. The generation of smoke during the initial short period of combustion would not pose any serious problem in steaming rice in households except for tarnishing utensils. When a fire must be kept burning for a long time, for boiling a soup or noodle in a restaurant for example, addition of lignite briquettes into a large burning stove generates smoke. Lignite briquettes are not suited to such uses.

(2) Industrial Sector

During the period of the monitoring survey, the study team visited 16 industrial facilities: lime kilns, potteries, a tobacco curing factory, rubber drying factory, paper mill, various food-processing factories, stove factories, blacksmiths, a bronze smelter. Most of them burn firewood and would require modifications to the facilities if they are to become able to burn lignite briquettes. Ironically, if such modifications are made they will become able to burn lignite itself rather than lignite briquettes only. If they could burn lignite, they have no logical need to burn lignite briquettes; they could burn lignite rather than lignite briquettes in place of firewood. Although firewood is becoming hard to come by as a result of the depletion of the forest resources, spent wood from the sawmills and old rubber trees are still so cheap that lignite briquettes can hardly compete in price.

Slaked lime blended into lignite briquettes suppresses the generation of sulfur dioxide when they are used as household fuel. However, most industrial furnaces operate at temperatures higher than that of cooking stoves. At such high temperatures the desulfurization by slaked lime cannot be expected. Therefore, from the standpoint of pollution control, lignite briquettes do not offer any advantage to industrial installations over lignite itself.

From the above, the possibility of lignite briquettes being used in the industrial sector is not high.

5-4 Price Forecast of Charcoal

5-4-1 Market Price of Charcoal and Firewood

From the consumers' point of view, lignite briquettes must be superior to other competing fuels not only in quality but also in price in order for lignite briquettes to be fully competitive with the competing fuels. To examine this important aspect of the price competitiveness of lignite briquettes it is necessary to investigate the market prices of charcoal and firewood as well as to estimate the anticipated retail prices of

lignite briquettes.

The prices of commodities in market-economies depend greatly on the supply-demand balance and production costs. At the same time, however, the price of one product is also affected by prices of its competitive products; that is, the price of charcoal will be influenced by the level of the quality of other fuels that compete with them in the same applications. This should be kept in mind in forecasting the price of charcoal. From the viewpoint of convenience, charcoal is better than firewood, and LPG is better than charcoal; the former is a competitive fuel with the latter. Therefore, the price of firewood will not exceed that of charcoal and the price of charcoal will not exceed that of LPG. Because of the recent restrictions on the cutting down of trees, the potential demands for charcoal and firewood will exceed the supply; consequently, their prices will increase to levels that are linked with the price of LPG. Recently, there is a tendency in which consumers choose between LPG and charcoal, and between charcoal and firewood, taking into consideration of the quality, price and uses of these fuels, rather than there being distinctive lines between LPG users and charcoal users or between charcoal users and firewood users depending on their income levels.

5-4-2 Method for Forecasting Prices of Charcoal

The price of charcoal was forecast by the method shown in Figure 5-3.

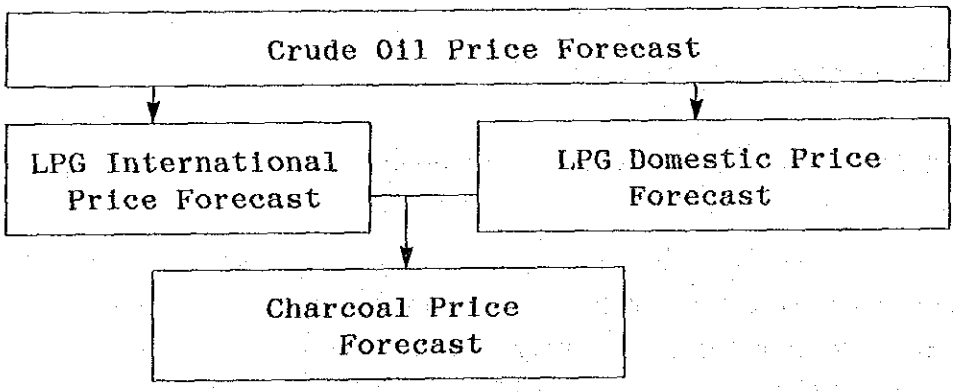

Figure 5-3 Simplified Flow of Charcoal Price Forecast

This price of charcoal is forecast using the causal method based on the the following assumptions.

The price of charcoal is influenced by the price of LPG, and at the same time is higher than that of firewood. Therefore, the retail price of LPG was forecast first, and from this the price of charcoal was forecast. The forecast price of charcoal and that of firewood were reconciled.

5-4-3 Current Price Situation of Charcoal, Firewood, and LPG

This section summarizes the trends of the prices of charcoal, firewood and LPG.

(1) Prices of Charcoal and Firewood and LPG

The price of charcoal varies according to the location, quality and means of sales. There is also a seasonal fluctuation. During the field survey period, the price varied from 4 to 6 Bahts for a one-kilogram bag and 50 to 180 Bahts for a 30 to 40 kilogram bag, or 1.5 to 5 Bahts per kilogram. The price decreases in the order of Bangkok, Central, Southern, Northern and Northeastern Regions. The average price is estimated at 5.5 Bahts for a one-kilogram bag and 110 Bahts for a large bag of 35 kilograms, or 3.1 Bahts per kilogram. An overwhelmingly larger amount is sold in larger bags; therefore, the average price may be regarded as 3.1 Bahts per kilogram. In contrast to charcoal, very little firewood is distributed. The unit for sale varies, as does the price which ranged from 0.2 to 1.2 Bahts per kilogram. Although the price of firewood is difficult to determine, the average price may be estimated to be below 1 Baht per kilogram. The prices of charcoal and firewood are on the rise throughout the kingdom as supplies become tight because of the decrease in the forest area and the ban on cutting down of trees.

As stated before, the price of LPG is controlled by the government for each region. In Bangkok, the price of LPG as of the end of August 1990 was 9.85 Bahts per kilogram.

Among charcoal, firewood, and LPG, the prices are determined by the relative convenience of each fuel type. LPG is superior to charcoal and charcoal to firewood in ease of ignition, cleanliness and the effects on the cooking places. Therefore, the price of LPG is naturally higher than that of charcoal and the price of charcoal is higher than that of firewood. The result of the surveys shows the price ratio among LPG, charcoal, and firewood was 10:3:1 in weight and 4:2:1 by heat content as of August 1990. Table 5-30 summarizes the retail prices of various fuels as of November and December 1989, collected during the survey.

Table 5-30 Retail Price of Various Fuels

Fuel	Retai Price Sales Price	US$/MMBTU	Note
Charcoal	5 B/kg	6.9	Bangkok/Chiang Mai Retail
	5 B/1.2kg	5.8	Phitsanulok Retail
	150 B/38kg	5.5	Phitsanulok Retail
	110 B/38kg	4.0	Phitsanulok Retail
	120 B/38kg	5.5	Chiang Mai Market
	5 B/1.5kg	4.6	Mahasarakham Retail
	80 B/24kg	4.6	Mahasarakham Retail
	5 B/1.5kg	4.6	Khon Kaen Retail
	16 B/4.5kg	4.9	Nakhon Rachasima Retail
	3 B/kg	4.2	Nakhon Si Thammarat Retail
Firewood	1,900 B/3m3	2.5	Chiang Mai Pottery
	530 B/3.55m3	0.6	Chiang Mai Brick Burner
	10 B/8.1kg	3.4	Chiang Mai Retail
Bagasse	25 B/ton	1.1	Chiang Mai Sugar Mill
Coal Briquettes	8 B/3kg	3.9	Chiang Mai Retail
	4 B/0.6kg	9.7	Chiang Mai Retail
Coconut Shell	300 B/ton	0.65	Chiang Mai Wholesale
Rice Husks	300 B/ton	0.19	Phitsanulok Retail
LPG	480 B/48kg	8.8	Chiang Mai Retail

Note:
(1) Net heating value for calculation, kcal/kg

Charcoal	7,000
Firewood	3,500
Bagasse, 50% moisture	2,115
Coal Briquettes	6,667
Coconuts Shell	4,500
Rice Husk, 8.7% moisture	3,820
LPG	11,000

(2) Firewood density used for calculation: 0.70gr/cm^3
(3) Exchange Rate: One US Dollar is 26 Bahts.

As may be seen from the table, LPG was priced twice charcoal and charcoal twice firewood. In spite of large differences in the distance of transportation, the price of charcoal did not very very much from one place to another.

(2) LPG Price

The price of LPG in the international market, import price, ex-refinery price and retail price in Thailand are summarized below.

1) International and Import Prices

The price of LPG has been linked with the price of crude oil. The FOB Middle East price has been between 80 and 110 percent of the price of Arabian Light Crude Oil, for example. The CIF Bangkok price of LPG has risen and fallen in response to the fluctuation in the price of LPG. Table 5-31 summarizes the changes in LPG and crude oil prices.

Table 5-31 Historical LPG Price at Houston USA and CIF Price at Bangkok

	International Price(US$/T) (Houston USA)		Crude Oil Price Spot (Ar Light)	Exchange Rate	Import Volume	CIF Price	
	C3	C4	US$/bbl	Bs/US$	1000 lit's	Bs/l	US$/T
1973	52.0	32.2	2.12	20.380	-	-	-
1974	86.2	131.2	10.41	20.380	-	-	-
1975	104.9	89.7	11.08	20.400	1.0	1.18	108.9
1976	108.7	102.3	11.91	20.400	-	-	-
1977	131.6	118.6	12.57	20.400	3.5	2.23	206.2
1978	129.0	104.1	12.87	20.390	58.5	2.00	185.0
1979	149.5	269.8	30.73	20.425	77.7	2.85	263.3
1980	224.7	260.8	36.23	20.630	134.8	4.93	450.9
1981	251.8	266.5	34.10	23.000	231.3	5.36	439.7
1982	221.6	297.4	31.72	23.000	425.5	5.06	415.1
1983	248.5	302.0	28.76	23.000	602.5	5.25	430.7
1984	224.7	247.1	28.06	27.150	721.3	4.18	290.5
1985	196.7	247.6	27.54	26.650	237.1	3.92	277.5
1986	125.4	138.9	14.10	26.130	107.4	1.91	137.9
1987	166.2	166.7	17.35	25.070	232.6	2.33	175.4
1988	114.9	133.6	13.40	25.000	276.3	2.23	167.9

Source: Based on Consultant's In-house Data

2) LPG Domestic Price

Table 5-32 summarizes changes in the ex-refinery price of LPG and

crude oil price. Table 5-33 summarizes the recent changes in the imported LPG and crude oil prices.

Table 5-32 Domestic Ex-Refinery LPG Price

	Ex-Refinery Bs/T	Taxes Bs/T	Total Bs/T	Total US$/T	International Crude Oil Price US$/BBL(Yr. Av.)
Aug. 01, 1973	777.1	510.8	1,287.9	63.2	2.89
Sept. 16, 1974	2,429.6	607.0	3,036.6	149.0	10.41
Dec. 11, 1974	2,279.6	450.1	2,729.7	133.9	10.41
Sept. 11, 1975	2,279.6	133.7	2,413.3	118.3	11.09
Sept. 01, 1977	3,139.7	183.8	3,323.5	162.9	12.57
Feb. 01, 1979	3,139.7	262.1	3,401.8	166.6	30.74
July 14, 1979	4,963.0	404.0	5,367.0	262.7	30.74
Feb. 09, 1980	7,173.3	542.9	7,716.2	374.0	36.24
Dec. 02, 1980	8,363.9	0.1	8,364.0	405.4	36.24
Feb. 05, 1981	8,511.6	0.1	8,511.7	370.1	34.28
Dec. 02, 1981	8,978.3	0.1	8,978.4	390.4	34.28
Feb. 18, 1982	8,377.6	0.1	8,377.7	364.2	31.75
Aug. 01, 1982	8,188.3	0.1	8,188.4	356.0	31.75
Mar. 29, 1983	8,188.3	0.1	8,188.4	356.0	28.78
Dec. 01, 1983	7,973.8	486.4	8,460.2	367.8	28.78
Jan. 06, 1984	7,893.4	486.3	8,379.7	308.6	28.06
Nov. 05, 1984	9,189.2	486.0	9,675.2	356.4	28.06
Jan. 03, 1985	9,205.5	484.7	9,690.2	363.6	27.55
Dec. 25, 1985	7,854.5	489.9	8,344.4	313.1	27.55
Jan. 02, 1986	7,887.3	489.9	8,377.2	320.6	14.11
Dec. 26, 1986	4,923.0	2,500.0	7,423.0	284.1	14.11
Jan. 04, 1988	5,546.6	2,500.0	8,046.6	312.9	13.81
Jul. 04, 1988	5,642.9	2,500.0	8,142.9	325.7	13.81
Jan. 02, 1989	5,109.0	2,500.0	7,609.0	304.4	16.35
Aug. 28, 1989	5,275.0	2,500.0	7,775.0	311.0	16.35

Source: Based on Oil and Thailand

Table 5-33 Imported Price of LPG

	Imported LPG Bs/T	Taxes Bs/T	Total Bs/T	Total US$/T	Internat'l Crude Oil Price US$/BBL (Yr. Av.)	Ex-Refinery Bs/T
Apr. 01, 1984	7,893.4	483.0	8,376.4	308.5	28.06	8,379.7
Nov. 05, 1984	8,001.3	880.4	8,881.7	327.1	28.06	9,675.2
Jan. 03, 1985	8,032.5	490.9	8,523.4	319.8	27.55	9,690.2
Dec. 11, 1985	7,010.7	490.9	7,501.6	281.5	27.55	8,344.4
Jan. 02, 1986	7,314.3	490.9	7,805.2	298.7	14.11	8,377.2
Dec. 09, 1986	3,858.5	2,501.0	6,359.5	243.4	14.11	7,423.0
Jan. 04, 1988	4,567.3	2,501.0	7,068.3	282.7	13.81	8,046.6

Table 5-33 Imported Price of LPG (Continued)

	Imported LPG Bs/T	Taxes Bs/T	Total Bs/T	Total US$/T	Internat'l Crude Oil Price US$/BBL (Yr. Av.)	Ex-Refinery Bs/T
Dec. 26, 1988	3,707.0	2,501.0	6,208.0	248.3	13.81	8,142.9
Jan. 02, 1989	3,711.4	2,501.0	6,212.4	248.5	16.35	7,609.0
Dec. 25, 1989	4,378.7	2,501.0	6,879.7	275.2	16.35	7,775.0

Source: Oil and Thailand

The price of LPG is totally under the control of the government at the wholesale as well as retail levels. There is a small difference between the metropolitan area and other provinces. The retail price of LPG in Bangkok is shown in Table 5-34. The tax on LPG was 2.5 Bahts per kilogram as of December 1988.

Table 5-34 Retail Price of LPG in Bangkok

	1983 Dec.1	1985 Jan.-Dec.	1986 Jul.1	1987 Aug.12	1988 Nov.25
LPG(Large),Baht/kg	9.46	9.46	9.46	9.85	9.85
US$/T	411	355	362	393	394
LPG(Small),Baht/kg	9.99	9.99	9.99	9.85	9.85
US$/T	434	375	382	393	394

Source: Oil and Thailand

5-4-4- Forecast of Charcoal Prices

In Thailand, charcoal will be partly replaced by LPG and the degree of replacement will be determined largely by the relationship between the price of LPG and that of charcoal.

(1) Forecast of LPG Price

The price of LPG is linked to that of crude oil throughout the world. The ex-refinery price of LPG in Thailand is also affected by the price of crude oil. On the other hand, the price of LPG separated from the

natural gas produced in the Gulf of Thailand should be determined by the price of natural gas and the operation cost of the LPG recovery plant. However, this LPG price cannot be independent of the international price and is also under the control of the government. It follows therefore that the domestic prices of LPG in Thailand are affected by the international price. Therefore, the price of LPG was forecast in this study based on the assumption that there is a relationship between the price of crude oil and the domestic price of LPG.

1) Forecast of International Crude Oil Price

The price of crude oil has fluctuated depending basically upon the relationship between production and reserves and between the demand and production capacity of OPEC countries. In the short term, they were affected by political situations in the Middle East. In the future, the price of crude oil will also be affected by other factors such as production by the Soviet Union. There seems to be a consensus among oil experts that the price of crude oil will increase gradually even on the fixed-price base without the effect of inflation. Table 5-35 summarizes the forecast price of crude oil. This forecast is made in reference to the forecasts of international research institutes.

2) Forecast of Import Price of LPG

The forecast of the import price of LPG as a function of the varying price of crude oil is summarized as follows. The FOB price of LPG in the Middle East was higher than the price of Arabian Light crude oil. Recently, however, the price of LPG has been lower than the crude oil price even on weight base, because the supply of LPG has exceeded the demand. In this study, the FOB price of LPG is forecast to be 95 percent of the crude oil price, because similar conditions are expected to prevail in the future. Freight and insurance costs are forecast to be US$30 and 44 per ton of LPG when the price of crude oil is between US$15 and 50 per barrel. Terminal charge, taxes, and distribution costs are forecast to be US$25, 2,500 Bahts, and 3,000 Bahts per ton of LPG, respectively. Table 5-36 summarizes the estimated price of imported LPG.

Table 5-35 Arabian Light Spot Price

(Unit: US$/bbl)

	Inflation Factor	Constant 1990 Price	Current Dollars
1970	0.335	4.03	1.35
1975	0.466	23.80	11.09
1980	0.652	55.58	36.24
1981	0.715	47.94	34.28
1982	0.760	41.78	31.75
1983	0.790	36.43	28.78
1984	0.819	34.26	28.06
1985	0.847	32.53	27.55
1986	0.866	16.28	14.11
1987	0.895	19.40	17.36
1988	0.925	14.93	13.81
1989	0.962	17.00	16.35
1990	1.000	21.75	21.75
(Jan-Jul)		(15.60)	(15.60)
(Aug-Dec)		(30.09)	(30.09)

	Inflation Factor	Low Case 1990 Price	Probable Case 1990 Price	Probable Case Current Price	High Case 1990 Price
1995	1.217	10.00	23.00	27.99	26.00
2000	1.480	11.00	25.00	37.00	28.00
2005	1.801	16.00	28.00	50.43	35.00
2010	2.191	18.00	30.00	65.73	40.00

Table 5-36 Price Estimation of Imported LPG (Weight Base)

Crude Oil Price (Arabian Light)						
US$/bbl	15	20	25	30	40	50
US$/Ton	110.5	147.4	184.2	211.1	294.7	368.4
LPG Price (US$/Ton)	109.3	140.0	175.0	200.5	280.0	350.1
Freight	30.0	32.0	34.0	36.0	40.0	44.0
Bangkok Pricing (CIF)	139.3	172.0	205.0	236.5	320.0	394.1
Terminal Charge	25.0	25.0	25.0	25.0	25.0	25.0
Sub-Total(US$/Ton)	164.3	197.0	234.0	261.5	345.0	419.1
(Bahts/kg)	4,108	4,925	5,850	6,538	8,625	10,478
Taxes	2,500	2,500	2,500	2,500	2,500	2,500
Distribution, etc.	3,000	3,000	3,000	3,000	3,000	3,000
TOTAL	9,608	10,425	11,350	12,038	14,125	15,978

3) Estimates of Domestic LPG Price

The ex-refinery price of LPG in Thailand is considered to be related with the international price of crude oil. Based on the past relation-

ship between them and the forecast price of crude oil shown above, the future ex-refinery prices of LPG are forecast and summarized in Table 5-37.

Table 5-37 Domestic LPG Price Forecast

(Unit; Bahts/Ton)

	Ex-Refinery	Taxes	Total	Arabian Light Yearly Av. Price (US$/bbl)
Actual				
Jan. 03, 1985	9,205.5	484.7	9,690.2	27.55
Jul. 04, 1988	5,642.9	2,500.0	8,142.9	13.81
Aug. 28, 1989	5,275.0	2,500.0	7,775.0	16.35
Forecast (Based on Constant Price)				
1995	7,000	2,500	9,500	23
2000	7,400	2,500	9,900	25
2005	7,900	2,500	10,400	28
2010	8,500	2,500	11,000	30

4) Forecast of LPG Retail Price

LPG marketed in Thailand consists of imported LPG and domestic products produced at refineries and separated from natural gas. The ex-refinery price of LPG was forecast based on past statistics, and 2 Bahts per kilogram were added to obtain the retail price. By using this method of forecasting, the forecast retail prices obtained turned out to be higher than the forecast imported prices, as should be the case. The forecast retail price of LPG is shown in Table 5-38.

Table 5-38 Retail Price Forecast of LPG

	Actual			Forecast (Based on Constant Price)			
	1986	1989	1990	1995	2000	2005	2010
Probable Case							
Bahts/Kg							
LPG(large)	9.46	9.85	11.05	11.5	11.9	12.4	13.0
LPG(Small)	9.99	9.85	11.05	11.5	11.9	12.4	13.0
Bahts/MMBTU							
LPG(large)	198.6	206.8	232.0	241.5	249.9	260.4	273.0
LPG(Small)	209.8	206.8	232.0	241.5	249.9	260.4	273.0

Note: Heating value of LPG is 12,000 Kcal/kg.

(2) Forecast of Charcoal Price

As stated in 5-8-1(1), the relative prices of charcoal, firewood, and LPG are determined by their relative convenience. LPG is superior to charcoal and charcoal to firewood in ease of use, in ease of ignition, cleanliness, and effects on conditions of the cooking place. Therefore, the price of LPG is higher than that of charcoal and the price of charcoal is higher than that of firewood. The result of the surveys showed that the price ratio of LPG to charcoal was 10:3 in weight and 2:1 on heating value.

Although it is likely that the difference between LPG and wood fuel in price on heat value will become smaller in the future because of the restrictions on cutting down of trees and the decrease of wood fuel resources, the price of charcoal will not exceed that of LPG except for charcoal used for special purposes, if any, nor will the price of firewood exceed that of charcoal. Therefore in this study it is forecast that the price of charcoal in large packages will reach 70 percent of the price of LPG by 1995 in consideration of the thermal efficiency of stoves for LPG and charcoal. After 1995, it is estimated that this relationship will hold.

Tables 5-39 and 5-40 show the forecast prices of charcoal in 35-kilogram and 1-kilogram package, respectively.

Table 5-39 Price Forecast of Charcoal with Large Bag

	Actual		Forecast (Based on Constant Price)			
	1989	1990	1995	2000	2005	2010
Probable Case						
Bahts/35 kg Bag	100	110	162	167	174	183
Bahts/kg	2.86	3.14	4.63	4.77	4.97	5.23
Bahts/MMBTU	104.3	114.8	169.1	174.9	182.3	191.1